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SMART Flow Facility Analysis

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EXECUTIVE SUMMARY

Because of the manufacturing company's diverse product line and high demand, the company has resulted to storing a huge portion of their finished products outside in a parking lot, while also using a third-party warehousing far off-site. With warehousing space and transportation dictating the cost, the objective is to combine the currently used third party warehouse with an accessory line for storage of all their finished product. The manufacturing facility currently has 650,000 sq. feet of usable land. The objective is to find the necessary space requirements of the new facility to determine if the facility can use their available land. The facility must be capable of handling peak operations; thus, all calculations were based on peak operations.

After simulating the inbound and outbound processes, we determined that the facility needs to have 44 bay doors. We calculated the number of necessary parking spaces assuming trailers stay for their maximum number of days. The facility needs 3 rows of 53 trailers for a total of 159 parking spaces.

We designed the facility for two alternatives, 20% growth and expected growth. The alternatives only affected the interior facility design. With expected growth, the facility will require a total of 822,384 square feet of land. With 20% growth, the facility will require a total of 855,304 square feet of land.

Both alternatives require the company to purchase new land. However, if the initial costs stay similar, then this facility is a good economic decision. Assuming a 12% MARR, if the initial cost raises by no more than $2.92 million, then using either of the depreciation methods, it will result in the company breaking even within 7 years in present worth money.

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CHAPTER 1: PROJECT OVERVIEW

1.1 INTRODUCTION

The goal of this project is to consolidate three separate business units into one larger unit. This unit will be the main hub for exporting and sorting finished products. Currently, they are storing their finished products outside in a parking lot along with a third-party warehouse located at least 45 miles away. However, this is an inefficient use of resources due to their cost of transportation and warehousing space. We will be designing a facility warehouse that will increase warehouse space while adding an accessory line. The facility must be designed to handle maximum operation. If the facility is unable to handle operations at any point, that would be considered a failure that must be avoided. Based on our calculations and design, we will determine if the available 650,000 sq. feet on the company's campus is enough space to warehouse all finished product.

1.2 OVERVIEW

They currently do not have room to store finished products indoors, so approximately a couple thousand finished products sit right outside the manufacturing facility. The company wants to expand its manufacturing facility to ramp up production, but to also consolidate their A, B, and C business units that are currently being leased to the manufacturing company, thus costing them a lot of money per year. If they were to consolidate all three buildings into their own manufacturing facility, then that would eliminate all leasing costs associated. Secondly, they currently use a facility in an undisclosable location which holds some of their finished products, but is mainly used to organize different goods to be loaded into trucks to be shipped to the customer. Before the company can do that, they need a warehouse to store all of their products and an area to consolidate and organize the goods to be shipped to the customer. This is where our SMART Flow Design Team comes in and designs a warehouse using the available 650,000 sq. ft. of land to handle all their needs.

1.3 OBJECTIVE

Our objective in solving this problem is two-fold. The first objective is to create a space where all manufacturing may be done within the walls of one large building instead of currently producing products within three separate smaller buildings. Moving from one building to the other not only causes more room for errors/damages when transferring products, but also decreases the level of efficiency. The second objective is to build a facility that can also store the finished products upon completion. Currently, to store the finished products, the company is paying for a truck-load of finished products to drive roughly 4 miles to an undisclosable location from the plant's location, drop off the products, then paying for an empty truck to drive back to the plant's location for the next round. This setup is not cost efficient. Therefore, we want to create an in-house storage facility within the new building so that products can be stored and sorted through before shipping them off to customers.

1.4 JUSTIFICATION

The company is currently manufacturing and producing products within three separate business units. Leasing the three buildings year after year has driven up the cost tremendously. Outside of the central facility, they are currently storing a couple thousand products on the empty parking lot. Storing their newly manufactured products outside could potentially wear away the paint and quality of the product over time. Their goal is to have our team design a building where all three business units could be consolidated into one company-owned building, thus eliminating the yearly leasing costs all together.

The company would like the new facility to accommodate manufacturing, receiving, shipping, and storage needs for the company's finished products. As mentioned previously, the company currently stores, organizes, and ships from their storage facility located 45 miles away from the manufacturing facility. Not only is the company paying for transportation costs to drop off the finished products in the undisclosable storage location, but they are also paying for the empty truck to drive 45 miles back to the plant's location. Additionally, they are paying for driver expenses too. The SMART Flow Design Team's objective is to design a building just a few hundred yards away from the central manufacturing facility to eliminate all leasing, transportation, and driver costs.

1.5 PROBLEM STATEMENT

The current concept includes an accessory line for Product A and Product B. Alternatively, we can leave no space for such lines and meet only current requirements. However, if their requirements change, it will cost significantly more to expand facility or reduce efficiency to reorganize the layout. Another concept we think we will design for is three-year growth. This means there will be unused space for the time being, and it will not be optimal unless the company meets projections. However, we avoid the possibility of later redesign or expansion leading to larger costs later. We have created a Minimum Success Criteria in order to measure our efficiency on an effective building layout.

Minimum Success Criteria

1. Determine facility Dimensions
2. Design Layout
3. Perform economic analysis
4. Accounts for growth
5. Considers expansion of accessory line
6. Reduce transportation costs
7. Produce a design for flow of products

CHAPTER 2: LITERATURE REVIEW

2.1 LITERATURE REVIEW

When designing the initial shell of the facility, it is important to ensure that the most cost-effective design is in place to allow for easier development and flow of goods. Because the facility will be developed from the ground up, using a “Regular Facility Shape” over an “Irregular Facility Shape” would be ergonomic to implement an efficient warehousing facility (refer to Figure 1 – Regular vs. Irregular Facility Shape).

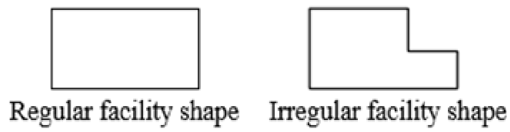

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Figure 1 – Regular vs. Irregular Facility Shape (Dukic)

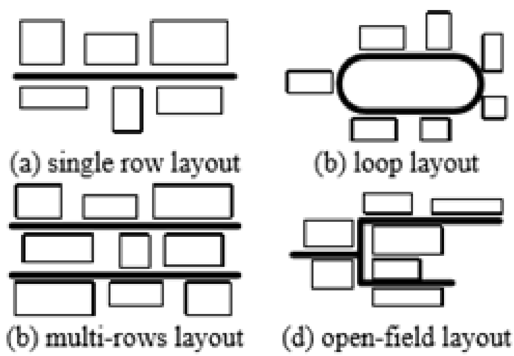

Figure 2 - Field Layout Options (Dukic)

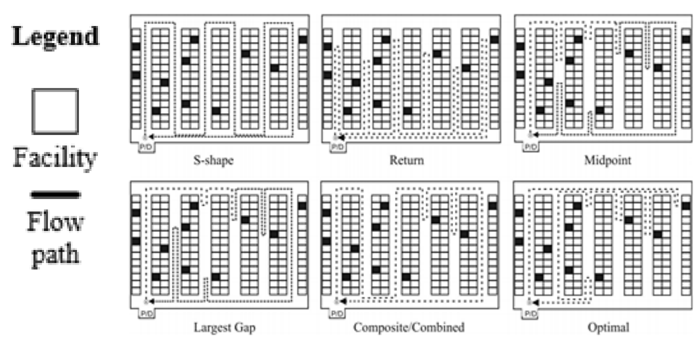

Figure 3 – Routes (Dukic)

Once the shell of the facility is determined, there are multiple forms of a warehouse layouts. In this case, there are single row, loop, multi-row, and open field layouts (refer to Figure 2 – Field Layout Options). Given that the goods handled will be heavy in weight, the less travel distance per pick will be the most efficient when considering safety and damage of the product. Therefore, using single row or multi row layout will be the most effective. Furthermore, a traditional layout with and without a cross lane, which includes single and multi-row layout, can provide an effective flow of goods based on the sufficient route (refer to Figure 4 – Traditional Layout). Pickers move based on S-shape, Return, Midpoint, Large Gap, Composite/Combined, and Optimal routes to get to their pickup and drop off locations (refer to Figure 3 – Routes).

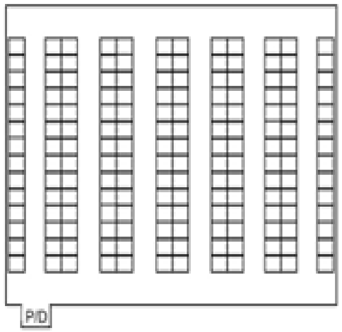
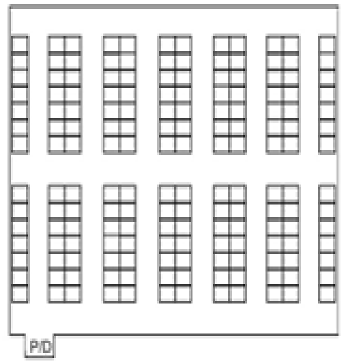

Figure 4 – Traditional Layout (Dukic, Cesnik, and Opetuck)

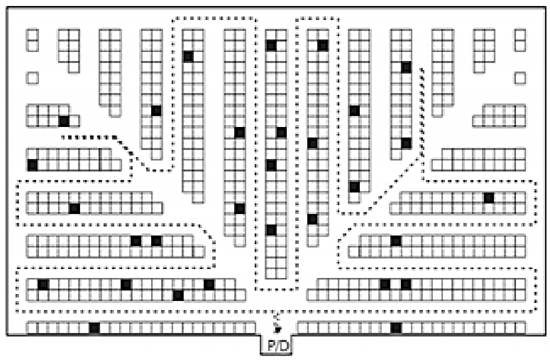

Figure 5 – Fishbone Layout (Dukic, Cesnik, and Opetuck)

With this in mind, there are three warehouse layout plans that can be contrasted in order to determine the most efficient flow, a traditional basic layout, a traditional with middle cross, or fishbone. These three layouts will be analyzed as each layout yields a different traveling distance for pickers, which is key when moving the product to their P&D points. According to Dukic, Cesnik, and Opetuck, "The fishbone layout is without any doubt an excellent layout for pallet picking", where the traveling distance for pickers is greatest with a traditional basic layout, followed by a fish bone layout, while a traditional layout with a middle cross yields the least traveling distance (29) (refer to Figure 5 – Fishbone Layout). The following table below depicts the distances yielded by the number of orders picked per layout in the study: (refer to Table 1 – S-Shape Routing Method and Table 2 – Composite Routing Method).

Table 1 – S-Shape Routing Method (Dukic, Cesnik, and Opetuck)

S- Shape Routing Method		Order Size	
		10	30
Warehouse Layout	Traditional (Basic)	258.7	375.8
	Traditional (Cross Aisle)	193.9	329
	Fishbone	227.5	351.9

Table 2 – Composite Routing Method (Dukic, Cesnik, and Opetuck)

Composite Routing Method		Order Size	
		10	30
Warehouse Layout	Traditional (Basic)	228.2	363.9
	Traditional (Cross Aisle)	182.8	309
	Fishbone	213.1	317.3

Furthermore, once the process flow for the freight has been designed, the placement and amount of shipping and receiving docks can be determined. The goal, as mentioned before is to minimize distance travel for pickers. Because a traditional layout with middle cross has been chosen, studies show that there are three optimal cases to choose the placements of loading docks:

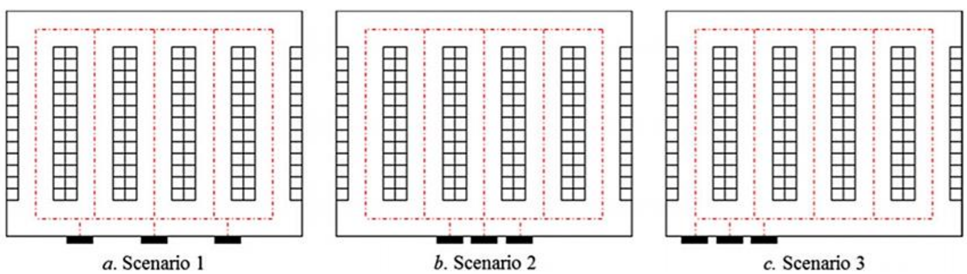

Figure 6 – Loading Docks (Tutam and White)

There are three dock doors that are equally spaced along one wall of the warehouse, scenario one, three dock doors that are centrally located on the wall with a specified distance between adjacent doors, scenario two, and three dock doors that are not centrally located along the wall, scenario 3 (refer to Figure 6 – Loading Docks). By having centrally located loading docks with a traditional layout with middle cross, travel distance would be minimized since “locating dock doors farther from the centerline of the warehouse increases the expected horizontal distance between dock doors and S/R locations” (246). The number of dock doors will be calculated based on the number of inbound and outbound trucks received by the facility.

Likewise, having a uniformed shaped building will allow for a synchronized movement of truck loads throughout the truck yard (refer to Figure 7 – Truck Flow). With a centrally located warehouse, trucks will be able to enter and exit from the same location, where trucks will move counterclockwise around the warehouse as they load and receive freight (refer to Figure 8 – Inbound and Outbound Trucks). This will enable truck drivers to move safely, as the building is on their left, easily visible as they drive. Similarly, the building will be constructed in manner that enables the driver to maneuver sufficiently throughout their apron space, which is the “space between the loading platform and the nearest obstruction” (3) (refer to Figure 9 – Apron Space). Illustrations provided below:

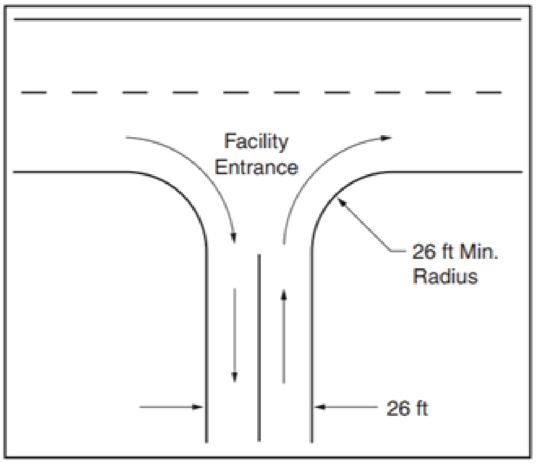

Figure 7 – Truck Flow (Accorsi)

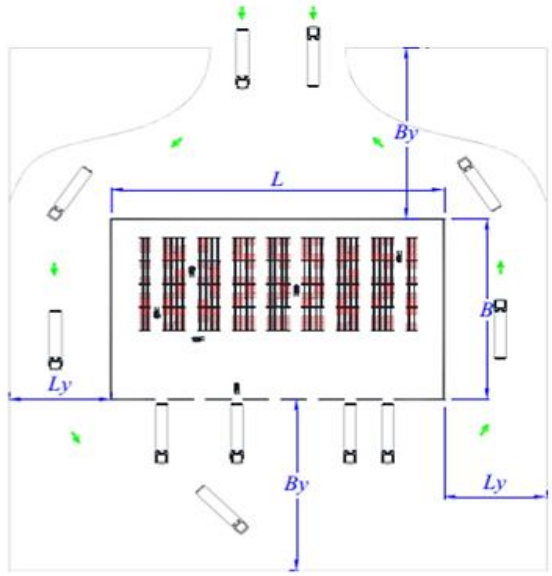

Figure 8 – Inbound and Outbound Trucks (Accorsi)

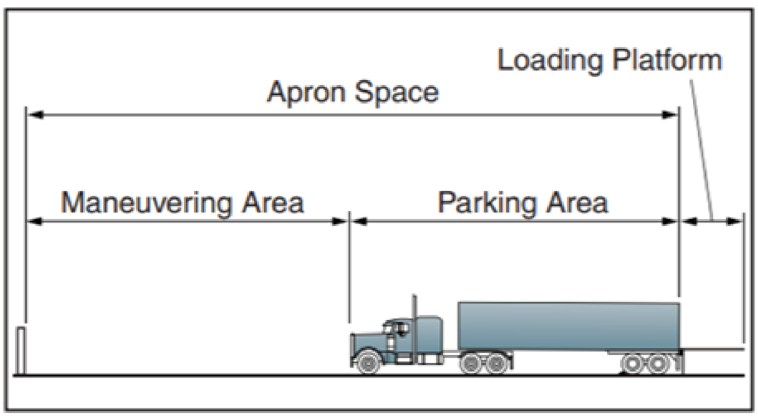

Figure 9 – Apron Space (Accorsi)

CHAPTER 3: PROBLEM SOLVING APPROACH

3.1 PROBLEM SOLVING APPROACH (HOW)

When designing this physical layout, our team must consider stable and seasonal business volumes, current and future volume demand growth, staging area for inbound and outbound shipping, storage areas, and product turn rates. While designing the facility, our team must also design for an efficient flow of goods. The team has designed interior and exterior physical layouts including truck parking, staging area, storage areas, and accessory. We performed various calculations to ensure an adequate amount of space needed for all operations. For example, the interior layout is designed to hold the maximum manufacturing storage needed at peak times. The exterior layout is designed to allow for the maximum domestic or international containers coming in and out. The bay doors are designed to handle the maximum inbound and outbound trucks expected to come through during peak times of the year.

The interior layouts are created using Microsoft Visio. We have also performed various economic analysis to highlight the benefits and profit-earning stages of the project. In order to determine how much space is needed for the staging areas, we have created and successfully ran simulations using ARENA. In the staging and storage areas, the storage racks must be designed effectively to optimize space for holding the finished products or even raw materials/parts. To determine the most effective physical layout, we must take into consideration all requirements that have been asked from the company themselves.

3.2 INCLUDE REQUIREMENTS

The first requirement is to design a physical layout of the facility with dimensions, and how many square feet is needed. The facility will be handling many different finished goods such as Product 1, Product 2, Product 3, and Product 4. We must take into account the many different variables such as seasonal trends, growth rates, product turnover rates to determine how many finished goods need to be held within the facility. We must also design storage rack systems so different finished products can be stacked and stored in the most optimal manner. The facility will also be holding parts, which may be used in the manufacturing plant or exported directly, so we need to design storage racks or bins to hold these parts. We need to identify their location within the facility, size, and quantity. The facility must be able to handle the finished goods coming in, so we must analyze the inbound receiving area to handle the amount of product coming in. We also need a consolidation or outbound staging area so finished goods can be organized and prepared to be directly shipped to the customer, thus taking away the need for the storage facility located 45 miles away from the plant.

Also, the company currently would like to include a post-production light assembly line known as a value-added area, where finished goods can be customized to dealer or customer specifications, instead of shipping parts to the dealer and having the dealer spend money to customize the product. The inbound and outbound areas also need to have an optimal amount of dock doors to optimize and handle the flow of products. Currently, the company has an accessory line for Product C, but would like us to take into consideration expanding the line or adding another to Product A or Product B. Our team needs to also take into consideration that the company has approximately 100 shipping containers a month on property and the exterior facility layout must be able to handle the inbound, outbound, and overall movement of these containers.

The second requirement which directly relates to the first is we need to analyze the flow of materials and goods, in order to develop the most optimal layout. Our goal is to reduce transportation or movement of products, reduce lead times, reduce touch points, increase flexibility to changes in customer demand, as well as optimize inbound and outbound flow of materials and goods.

Major System Interfaces:
1. Finished Goods, and Parts Storage area (Storage racks and bins)
2. Outbound Staging Area
3. Inbound receiving Area
4. Dock doors
5. Accessory Department
6. Exterior Container Staging and Handling

3.3 GANTT CHART

We have created a schedule to highlight all of our major deadlines and due dates. The Gantt Chart shows the duration for each assignment and when it is expected to be completed. Below is a SMART Flow Analysis Schedule (refer to Figure 10 – Gantt Chart).

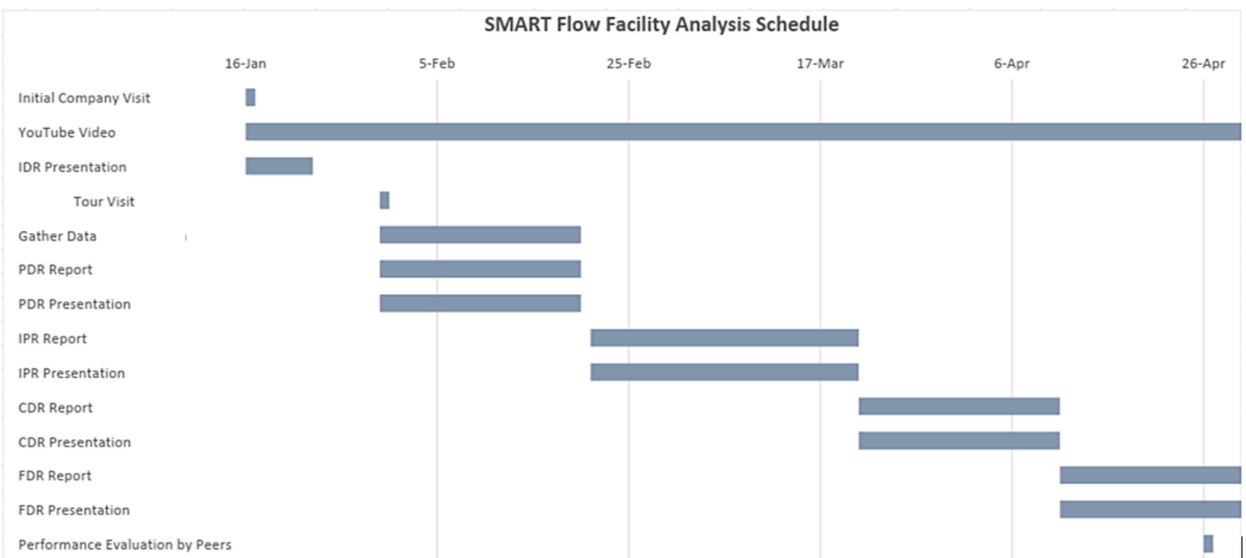

Figure 10 – Gantt Chart

3.4 PROJECT MANAGEMENT

3.4.1 Responsibilities

Each group member is responsible for different parts of the project. We have created a System Definition Matrix, or a breakdown of each group member's responsibilities throughout the course of this semester (refer to Table 3 – System Definition Matrix).

Table 3 – System Definition Matrix

	Pete Suktankar	Chantal George	Matthew Geiger	Eric Wilson
Literature Review				Performing literature review on a variety of facility layout ideas on KSU library google scholar galileo and google; will present finding to group members
Inventory Management	Determining seasonality and maximum inventory storage needs; will model weekly export and production data	Verify analysis; make any necessary changes/additons		
Facility Layout	Designing facility layout and alternatives based on inventory data, accessory line implementation, and outdoor needs		Help in design original creation, alternatives, and validate spacial needs	
Report Formatting		Making sure content is formatted properly and effectively for ease of reading		
Coordinator		Coordinates with to schedule tour and facility visits and collect data		
Economic Analysis			Perform economic analysis to either prove or disprove the need for the facility	

3.4.2 Schedule

We have created a detailed schedule of when events are due and by when we anticipate completing it. We have also included the duration or amount of days we expect to need for completing the task. Below is a schedule for the following project (refer to Table 4 – Schedule Overview).

Table 4 – Schedule Overview

Tasks/Deliverables	Start Date	Days to Complete
Initial Company Visit	16-Jan	1
YouTube Video	16-Jan	105
IDR Presentation	16-Jan	7
Tour Visit	30-Jan	1
Gather Data	30-Jan	21
PDR Report	30-Jan	21
PDR Presentation	30-Jan	21
IPR Report	21-Feb	28
IPR Presentation	21-Feb	28
CDR Report	21-Mar	21
CDR Presentation	21-Mar	21
FDR Report	11-Apr	21
FDR Presentation	11-Apr	21
Performance Evaluation by Peers	1-May	1

3.5 BUDGET

Our sponsor for this project is the manufacturing company. Currently the company is estimating the project to cost nearly $47.5 million, most of which will be used to make the land buildable, as it currently sits on top of granite which needs to be leveled. We will later be receiving a more accurate break down of how much money we will have to work with, not including the money for land development as the company doesn't want us to take land development into consideration. Our team will then use this amount as our budget for our project.

3.6 MATERIAL REQUIRED/USED

We will analyze the layout in AutoCAD to ensure the dimensions will work. We will run simulations to analyze and optimize flow of goods and materials, based on data provided by the company to be sure the facility can handle their required storage product load. We will then be able to use these simulations in combination with our layout to ensure touch points and transportation distances are reduced, thus leading to lower costs, better quality, and shorter lead times.

3.7 RESOURCES AVAILABLE

In order to do the facility layout, we currently plan on using AutoCAD, and ARENA simulation software to analyze the layout and flow of goods, which are available from Kennesaw State University. Our other main resource is the manufacturing company who will be providing us with the data and any information we need to complete the project.

CHAPTER 4: PHYSICAL LAYOUT

4.1 INTERIOR LAYOUT

4.1.1 Calculations

This new facility is designed to handle the busiest day the company could possibly have over the 3-year period given. Also, the company wanted us to analyze the given data as a baseline as well as develop an alternative facility that could handle 20% growth. First, we began by collecting the total production data (refer to Table 27 – Production Data A through Table 34 – Production Data H in Appendix C) and the sales data (refer to Table 35 – Sales Data A through Table 36 – Sales Data B in Appendix C). This production data given was the entire production data for the company worldwide, so we needed to narrow down how much product would be entering thru this facility. This was done by taking the given percentage of receipts for and multiplying it across each month of domestic production to get an exact number of products needed to be stored in the facility shown in (refer to Table 27 – Production Data A through Table 34 – Production Data H in Appendix C). Next, we then took the production and holding numbers and subtracted out the sales for each month (refer to Table 35 – Sales Data A through Table 36 – Sales Data B in Appendix C) to gather our total ending inventory each month (refer to Table 39 – Ending Inventory A through Table 40 – Ending Inventory B in Appendix C).

Table 5 – Daily Outbound Distribution

% Daily Outbound Distribution	
Monday	150%
Tueday	125%
Wednesday	100%
Thursday	75%
Friday	50%

The company ships more frequently earlier in the week than later, so in order to account for that we used a distribution shown in Table 5 (refer to Table 5 – Daily Outbound Distribution). In order to figure out which day would have an influx over the average amount of products being shipped outbound, we used local plant production refer to Table 27 – Production Data A through Table 34 – Production Data H in Appendix C). To begin, the company only operates Monday through Friday which is 20 days per month. Therefore, we took the production, sales numbers, and ending inventory to get the average daily values for each product line shown from Table 27 – Production Data A through Table 34 – Production Data H in Appendix C. Then, in order to apply our percentage distribution, we multiplied the percentage of the day by the daily production average and the daily sales. Next, we calculated our ending inventory difference which would show us how much inventory each day differed from the average. We did this across ever month and choose the maximum difference we could find (refer to Table 6 – Maximum Difference). This was the greatest difference from the average, which was generally on Fridays as this in when the company had the least being shipped out so product inventory was building up. We also needed values for if the company had 20% growth. We used our maximums from the baseline and multiplied by 120% giving us the values in Table 7 – Maximum 20% Growth).

Table 6 – Maximum Difference

MAX diiference	
Product 2	68.55
Product 3	22.8
Product 4	72.4
Product 5	20.3

Table 7 – Maximum 20% Growth

max difference 20% growth	
Product 2	82.26
Product 3	27.36
Product 4	86.88
Product 5	24.36

4.1.2 Crate Square Footage and Dimensions

The next step before trying to calculate the square footage needed is that we calculated the exact square footage each product took up while in a crate by converting the dimensions to feet. Once this was done, we took the length and multiplied by the width to figure out the square footage of how much floor space would be need for each product line shown in Table 8 (refer to Table 8 – Pallet Size Dimensions).

Table 8 – Pallet Size Dimensions

	Products	Dimensions	Length (ft)	Width (ft)	Sq Feet
	Redacted	dims(ft)	8.41	4.74	39.85
	Redacted	dims(ft)	4.27	5.40	23.02
	Redacted	dims(ft)	10.46	6.58	68.86
	Redacted	dims(ft)	7.14	6.64	47.42
	Redacted	dims(ft)	2.75	3.11	8.54
	Redacted	dims(ft)	1.66	2.08	3.46
	Redacted	dims(ft)	2.66	6.45	17.15
	Redacted	dims(ft)	3.24	3.33	10.78
OPE/MPE	Pallet Size		4.00	3.33	13.33
8 per Pallet					

4.1.3 Inventory Storage Space Requirements

Now that we have our ending inventory for each month (refer to Table 39 – Ending Inventory A through Table 40 – Ending Inventory B in Appendix C). We used Microsoft Excel to find the maximum number we would have to hold for each product. Then we were able to divide by the stack heights given by the company to figure out the number of crates that would take up floor space as height was not a concern in designing the facility. Now that we have the number of stacks needed for each product line, we multiplied by the sq. ft each crate would take up which was calculated earlier. We then were able to get the sq. footage needed to store each product the company produced. We summed these up to get 138,903 sq. ft as our baseline storage space required for the facility (refer to Table 9 – Inventory Sq. Feet).

Table 9 – Inventory Sq. Feet

	inventory	stack height	#of stacks	sq ft crate	sq ft
MAX: Product 1	1,829	5	366	17.15	6,277
MAX: Product 2	1,414	6	236	23.02	5,433
Max: Product 3	1,608	4	403	68.86	27,751
Max: Product 4	2,638	5	528	47.42	25,038
Max: Product 5	5,998	4	1,500	39.85	59,775
Max: Product 6	326	2	163	3.46	564
Max: Product 6	213	2	107	10.78	1,153
Max: Product 7	4,535	3	1,512	8.54	12,912
				Sum=	138,903

We used the exact same approach for our design accounting for growth except instead of selecting the max inventory over the 3 years of data collected, we took the maximum over the first year. We did this because our data already had a different growth percentage in it, so we needed to remove that prior to adding 20% growth (refer to Table 10 – 20% Growth Inventory Sq. Feet). Then we took that maximum value for each product and multiplied by 120% to get our maximum inventory accounting for 20% growth. We then followed the same steps above to calculate the square footage for the new growth rate. This ended up being 150,161 sq. ft. of storage space (refer to Table 39 – Ending Inventory A through Table 40 – Ending Inventory B in Appendix C).

Table 10 – 20% Growth Inventory Sq. Feet

	20% Growth Inventory				
	inventory max	stack height	#of stacks	sq ft crate	sq ft
MAX: Product 1	1,826	5	366	17.15	6,277
MAX: Product 2	1,518	6	253	23.02	5,824
Max: Product 3	1,321	4	331	68.86	22,793
Max: Product 4	2,744	5	549	47.42	26,034
Max: Product 5	7,198	4	1,800	39.85	71,730
Max: Product 6	391	2	196	3.46	678
Max: Product 6	246	2	123	10.78	1,326
Max: Product 7	5,442	3	1,815	8.54	15,500
				Sum=	150,161

4.1.4 Layout

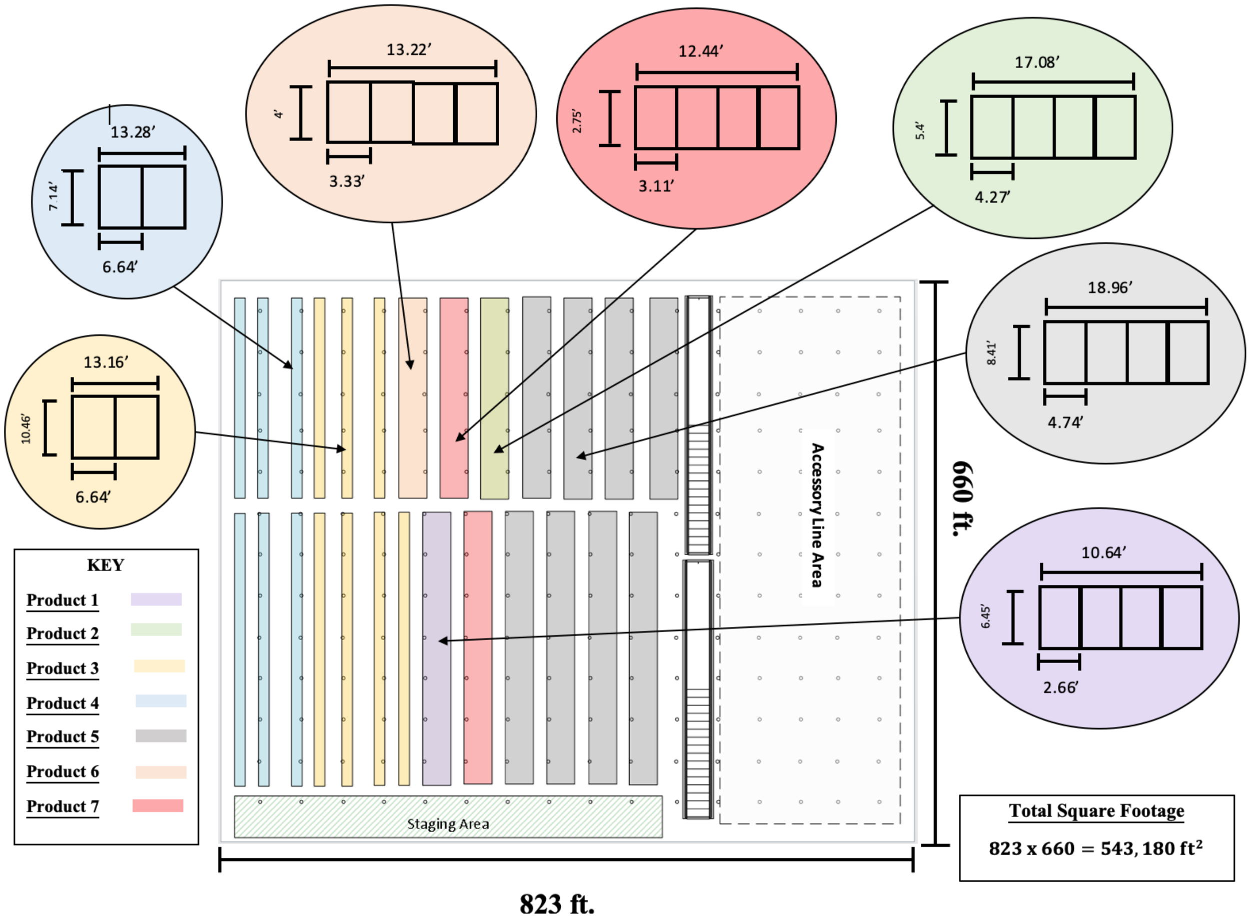

Figure 11 - Interior Layout Expected Growth

As seen in Figure 11, our expected growth physical layout of the warehouse was designed to handle inventory storage, staging, and accessory lines. With some products requiring the racks being only 2-wide and some 4-wide due to sizes of the products, we needed to use different storage area widths, which was calculated by using the dimensions of the product as well as the number of racks the facility needs to be able to hold on the busiest day. The bigger aisles for products 1 and 2 needed 16-foot aisle widths, while all other products could be handled with a 9-foot aisle. Structural poles were added every 50ft shown by the dots in Figure 11. We aligned the aisle with the structural poles so that we would not have any poles in the middle of aisles that could impede forklift and movement through the facility. Wherever a pole is placed along a storage area, there will not be a stack of racks which was accounted for when we did our interior layout. Products were also organized with the longest side facing the aisle as that is the side of the product that the forklift will pick up.

After laying all product storage spaces out with varying 16ft and 9 ft. aisles, we calculated that we would need 244,241 square footage of aisle space. Based on the newly found aisle space, inventory storage requirements, staging area, and accessory lines, we calculated that the facility will need a width of 823 ft. and a length of 660 ft. This approximates they will need approximately 543,180 ft. for the warehouse (refer to Figure 11 – Interior Layout Expected Growth) for the expected growth of the company.

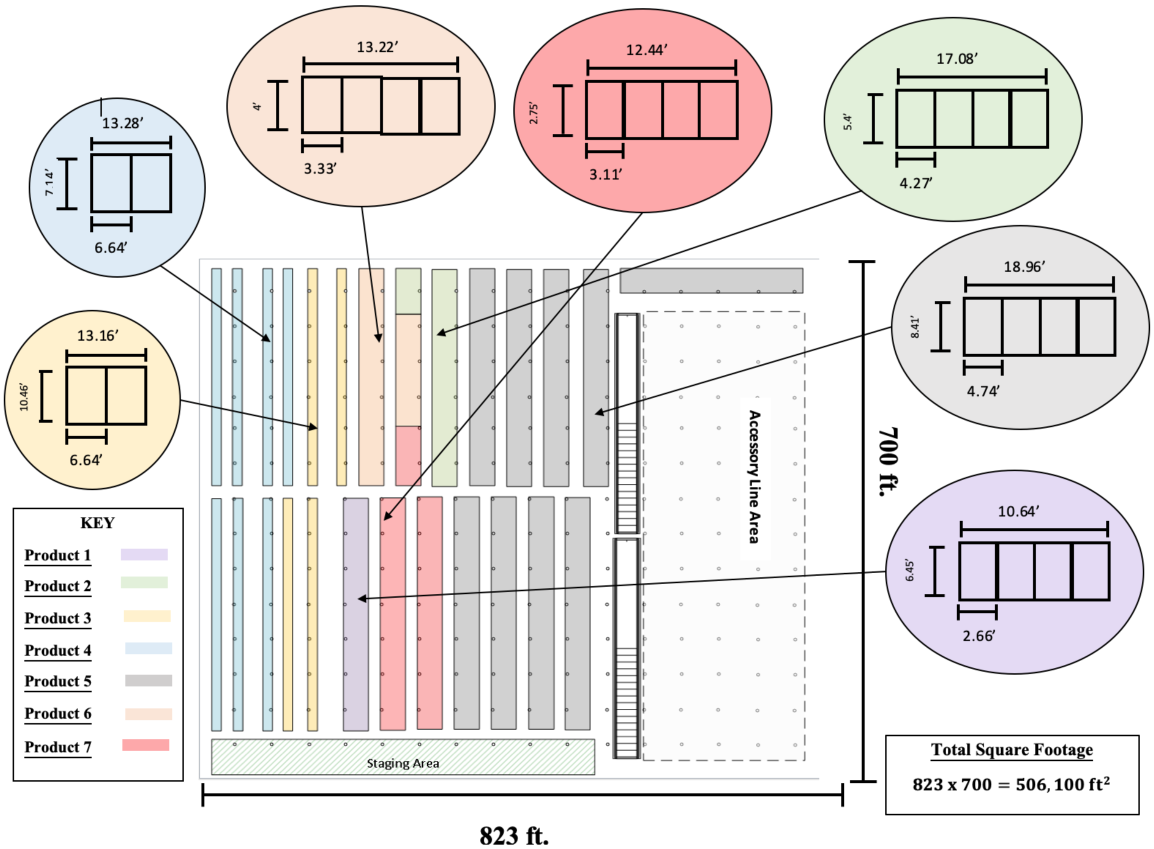

Figure 12 – Alternative Interior Layout Expected Growth

As seen in Figure 12, our new alternative interior physical layout of the warehouse was designed to handle inventory storage, staging, and accessory lines but for 20% growth. We gathered the additional inventory storage needs shown in Table 10. We used the same structural and aisle requirements as the original, but we accounted for the additional products required for inventory storage. After laying all the additional product storage spaces out with varying 16 ft. and 9 ft. aisles we calculated that we would need 265,843 square footage of aisle space. Based on this space, inventory storage requirements, staging area, and accessory lines, we calculated that the facility will need a width of 823 ft. and a length of 700 ft. This approximates they will need a 576,10 ft. warehouse (refer to Figure 12 – Alternative Interior Layout Expected Growth) for the expected growth of the company.

4.2 EXTERIOR LAYOUT

4.2.1 Inbound Trucking

In order to determine how many trucks were inbound, we took a look at our receipts (refer to Table 37 – Receipts A through Table 38 – Receipts B in Appendix C). We then found the maximum amount of each product line that would be brought in each month over the three years of data. We then divided this number by the number of products that can fit in each truck in order to get the number of trucks each month for each product. Then we divided that value by our 20 workdays per month to get the daily number of trucks we can expect to bring products in and totaled this amount, which came to 36 inbound trucks for our baseline (refer to Table 11 – Inbound Truck Maximum).

Table 11 – Inbound Truck Maximum

	inbound max	# per truck	# of trucks	# trucks per day
MAX: Product 1	1,079	41	27	2
MAX: Product 2	1,560	40	39	2
Max: Product 3	881	10	89	5
Max: Product 4	2,769	16	174	9
Max: Product 5	7,130	26	275	14
Max: Product 6	150	30	6	1
Max: Product 6	7	30	1	1
Max: Product 7	1,057	41	26	2
			Total inbound:	36

We used the exact same procedure as our baseline to calculate the number of inbound trucks for our 20% growth except instead of using the maximum over three years, we found the maximum over the first year to remove any growth already given in our baseline data. Then we multiplied those values by 120% to get our new inbound max for each product. This was then divided out the same way as the baseline to get our new daily inbound of 37 trucks for our facility that accounts for 20% growth (refer to Table 12 – Inbound Truck 20% Growth).

Table 12 – Inbound Truck 20% Growth

		20% Growth		
	inbound max	# per truck	# of trucks	# trucks per day
MAX: Product 1	1,178	41	29	2
MAX: Product 2	1,151	40	29	2
Max: Product 3	568	10	57	3
Max: Product 4	3,277	16	205	11
Max: Product 5	6,708	26	258	13
Max: Product 6	1,443	30	49	3
Max: Product 6	57	30	2	1
Max: Product 7	1,268	41	31	2
			Total inbound:	37

4.2.2 Outbound

The outbound number of trucks on average was 114, but in order to account for the heavy number of trucks that arrive on Monday, we used our distribution (refer to Table 13 – No Growth) and applied it to our average to get a proper maximum amount of outbound trucks, which generally occurs on Mondays.

Table 13 – No Growth

No Growth				
	Distribution	Outbound	Not Full	Full
Monday	1.50	171	105	66
Tuesday	1.25	143	88	55
Wednesday	1.00	114	70	44
Thursday	0.75	86	53	33
Friday	0.50	57	35	22

For our baseline, we calculated the maximum number of outbound trucks daily as 171, while for our 20% growth that number jumps to 206 shown in Table 14 (refer to Table 14 – 20% Growth).

Table 14 – 20% Growth

20% Growth				
	Distribution	Outbound	Not Full	Full
Monday	1.50	206	126	79
Tuesday	1.25	171	105	66
Wednesday	1.00	137	84	53
Thursday	0.75	103	63	40
Friday	0.50	69	42	26

4.2.3 Simulation on Trucks and Bay Door Use

To find the number of bay doors needed, we used Arena software to simulate inbound trucks and outbound trucks. We based our simulation on the maximum number of inbound and outbound trucks present in a day. We calculated 37 maximum inbound trucks and 206 maximum outbound trucks (refer to Chapter 4.2 – Exterior Layout). This is based on a total growth of 20% with Monday outbound truck volume being 150% of the daily average using data from the busiest day. We created a simulation to determine the number of the bay doors, set as a resource, needed to efficiently serve the inbound and outbound trucks without much queue (refer to Figure 13 – Simulation Process).

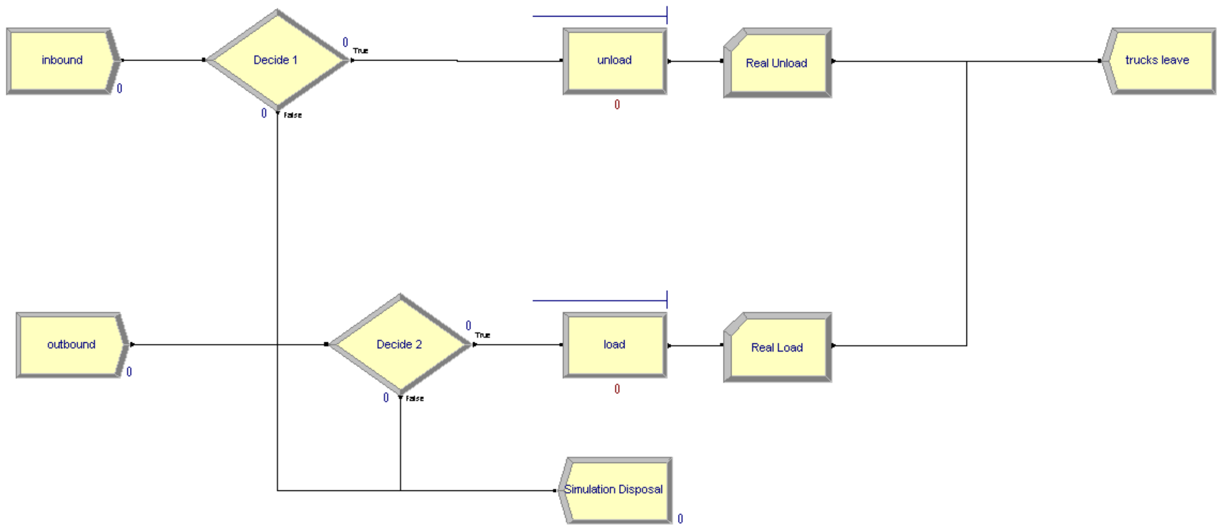

Figure 13 – Simulation Process

The inbound trucks arrive from 6 am to 3:30 pm. The outbound trucks are present from 11 am to 5 pm. Thus, the workday is 11 hours (refer to Figure 18 – Run Setup in Appendix C). In our simulation, time 0 is 6 am and 11 hours in is 5 pm.

4.2.4 Inbound Trucks

The 37 inbound trucks arrive within 9.5 hours. We modeled this as a creation module with an exponential distribution with the time between arrivals averaging (9.5/37) hours (refer to Figure 19 – Create in Appendix C). This means that in reality, there was randomness and chance. Maybe no trucks arrive for 30 minutes followed by 3 truck arrivals in 10 minutes.

The inbound trucks stop arriving at 3:30 pm. However, our simulated creation module had no scheduled stop feature. Instead, we created a decide feature to decide if inbound trucks were truly valid. Any inbound trucks that arrived after 9.5 hours were automatically disposed into a simulation trash disposal and not involved in any processes (refer to Figure 20 – Decide and Figure 21 – Dispose in Appendix C). The inbound trucks take an average of 30 minutes to unload. This means the bays are required to be in use for that amount of time. Thus, we set the inbound truck entity to need one bay door using a seize delay release function with a triangular distribution using a minimum of 0.25 hours, a mode of 0.5 hours, and a maximum of 0.75 hours. The triangular distribution is to account for variation in time it takes to unload a truck. The seize delay release functions means that the truck uses the bay door for the entirety of the process and then lets the bay door become available to other trucks. After the truck leaves the bay door, it gets recorded and exits the process (refer to Figure 22 – Record and 26 – Trucks Leave Dispose in Appendix C).

4.2.5 Outbound Trucks

The outbound truck is very similar to the inbound truck process. However, we had to make some changes in the simulation due to limitations of software that still match it with its use in real life. The loading of an outbound truck is a leading process and takes an average of an hour. However, the software does not anticipate the creation of an entity. In other words, the software cannot predict when a truck will enter. Thus, when setting up its Decide module, instead of not allowing any trucks after hour 5 (11 am) as one might expect, the simulation does not allow any trucks after hour 4 (10 am) to run through the process of loading. The loading process is then for simulation purposes a lagging feature averaging a 1-hour lag.

The 206 outbound trucks arrive within 6 hours. We simulated this as a creation module with an exponential distribution with the time between arrivals averaging (6/206) hours (refer to Figure 24 – Create Outbound in Appendix C). This meant just as it is in real life, there was randomness and chance. Maybe no trucks arrive for 30 minutes followed by 3 truck arrivals in 10 minutes. The outbound trucks start arriving at 10 am. However, our simulated creation module had no scheduled start feature. Instead, we created a decide feature to decide if outbound trucks were truly valid (refer to Figure 25 – Decide 2 in Appendix C). Any outbound trucks that arrived before 4 hours were automatically disposed into a simulation trash disposal and not involved in any processes (refer to Figure 26 – Simulation Disposal in Appendix C).

The outbound trucks take an average of 1 hour to load. This means the bays are required to be in use for that amount of time. Thus, we set the truck outbound truck entity to need one bay door using a seize delay release function with a triangular distribution with a minimum of .5 hours, a mode of 1 hour, and a maximum of 1.5 hours (refer to Figure 27 – Process in Appendix C). The triangular distribution is to account for variation in time it takes to load a truck. The seize delay release functions means that the truck uses the bay door for the entirety of the process and then lets the bay door become available to other trucks. After the truck leaves the bay door, it gets recorded and exits the process (refer to Figure 28 – Record 2 and Figure 29 – Dispose 2 in Appendix C).

4.2.6 Process Analyzer for 20% Growth Rate

We used process analyzer to allow us to quickly view the results of changing the number of available bay doors. We ran the simulation from 50 down to 30 bay doors. Arena was set up for 100 iterations (simulations) on each bay door and the results of the 100 iterations were averaged. We decided that we wanted to track a few key variables as our results. These were bay door utilization, maximum number of inbound trucks in queue, maximum number of outbound trucks in queue, maximum queue time for inbound trucks, and maximum queue time for outbound trucks. The objective is to minimize the maximum queue time and number of trucks in queue with queue time possessing greater importance. We also want to minimize the number of bay doors needed as the bay doors take up interior space. This is our projected busiest day at 20% growth, so most days, many bay doors will sit idle. It needs to be considered that adding bay doors later, if it is needed, will be more expensive than designing them at the beginning. Using 44 bay doors proves to be optimal. The expected maximum queue time for any truck is 0.107 hours or 6.42 minutes. The facility will not likely deal with this sort of a day often. The simulation ran the busiest day at 20% growth from current operations (refer to Table 15 – Process Analyzer for 20% Growth Rate).

Table 15 – Process Analyzer for 20% Growth Rate

	Scenario Properties				Control	Responses				
	S	Name	Program File	Reps	bay doors	bay door utilization	Max outbound truck Queue time	Max inbound truck Queue time	Max # outbound trucks in Queue	Max # inbound trucks in Queue
1		50 Bay Doors	12 : Senior D	100	50	0.439	0.021	0.010	1.17	0.24
2		49 Bay Doors	12 : Senior D	100	49	0.448	0.031	0.013	1.42	0.31
3		48 Bay Doors	12 : Senior D	100	48	0.457	0.044	0.021	1.93	0.38
4		47 Bay Doors	12 : Senior D	100	47	0.466	0.051	0.027	2.37	0.57
5		46 Bay Doors	12 : Senior D	100	46	0.478	0.067	0.037	3.09	0.66
6		45 Bay Doors	12 : Senior D	100	45	0.488	0.089	0.052	3.95	0.93
7		44 Bay Doors	12 : Senior D	100	44	0.498	0.107	0.066	4.74	1.07
8		43 Bay Doors	12 : Senior D	100	43	0.513	0.140	0.096	6.04	1.21
9		42 Bay Doors	12 : Senior D	100	42	0.521	0.158	0.110	6.75	1.37
10		41 Bay Doors	12 : Senior D	100	41	0.535	0.181	0.137	7.69	1.70
11		40 Bay Doors	12 : Senior D	100	40	0.540	0.203	0.140	8.36	1.64
12		39 Bay Doors	12 : Senior D	100	39	0.555	0.256	0.186	10.08	2.24
13		38 Bay Doors	12 : Senior D	100	38	0.567	0.303	0.222	11.68	2.24
14		37 Bay Doors	12 : Senior D	100	37	0.578	0.381	0.297	14.41	2.71
15		36 Bay Doors	12 : Senior D	100	36	0.591	0.441	0.359	16.45	3.02
16		35 Bay Doors	12 : Senior D	100	35	0.597	0.528	0.438	19.45	3.39
17		34 Bay Doors	12 : Senior D	100	34	0.605	0.635	0.541	22.80	3.88
18		33 Bay Doors	12 : Senior D	100	33	0.611	0.808	0.681	28.72	4.13
19		32 Bay Doors	12 : Senior D	100	32	0.613	0.875	0.756	30.88	4.56
20		31 Bay Doors	12 : Senior D	100	31	0.617	1.040	0.898	36.36	5.03
21		30 Bay Doors	12 : Senior D	100	30	0.621	1.172	1.051	41.03	5.35

Using the data from Process Analyzer 20% growth, we used Excel to graph the maximum queue time in minutes of both outbound and inbound trucks vs the number of the bay doors. The outbound trucks have the highest maximum queue time. The graph shows us the shape. From the shape, we know we should expect diminishing marginal returns for each additional bay door we add (refer to Figure 14 – Max Queue Time vs. Number of Bay Doors for 20% Growth).

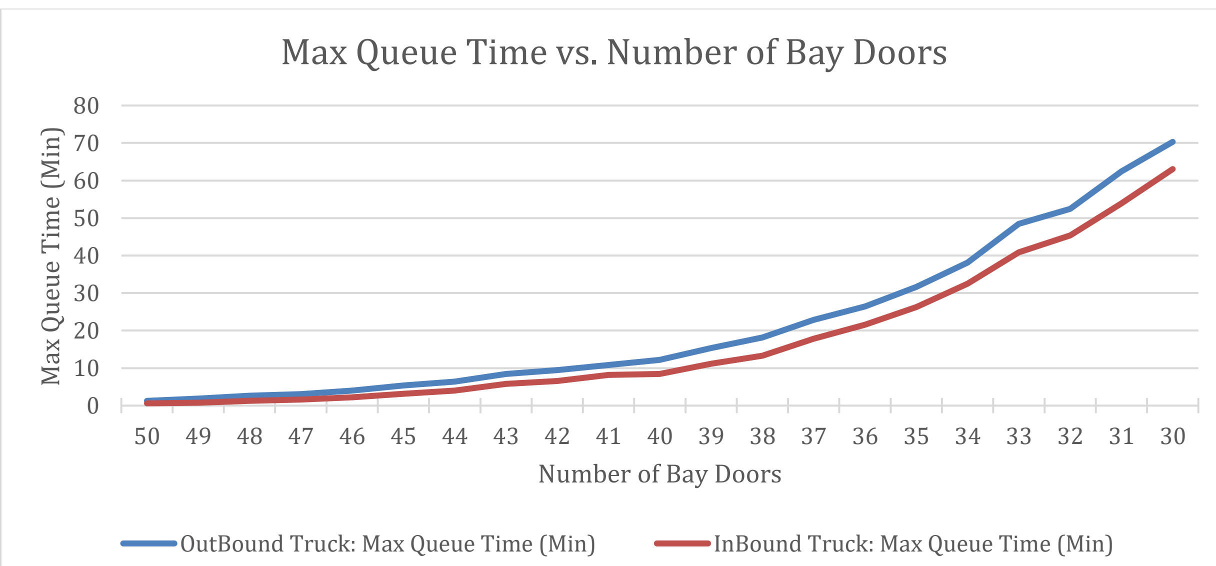

Figure 14 – Max Queue Time vs. Number of Bay Doors for 20% Growth

4.2.7 <u>Process Analyzer – Expected Growth</u>

Arena ran the same simulation only changing the number of trucks to match the maximum day of our expected growth over the next 3 years instead of at 20% growth. The outbound trucks were reduced to 171 trucks in the day and the inbound trucks were reduced to 36 in a day (refer to Table 11 – Inbound Truck Maximum and Table 12 – Inbound Truck 20% Growth). Again, Process Analyzer tracked the bay door utilization, maximum number of inbound trucks in queue, maximum number of outbound trucks in queue, maximum queue time for inbound trucks, and maximum queue time for outbound trucks. At our expected growth, on our busiest day we expect the maximum queue time for any truck to wait to be 0.02 hour or 1.2 minutes (refer Table 16 – Process Analyzer at Expected Growth).

Table 16 – Process Analyzer at Expected Growth

	Scenario Properties				Control	Responses				
	S	Name	Program File	Reps	bay doors	bay door utilization	Max outbound truck Queue time	Max inbound truck Queue time	Max # outbound trucks in Queue	Max # inbound trucks in Queue
1		50 Bay Doors	1 : No Growt	100	50	0.377	0.001	0.000	0.04	0.00
2		49 Bay Doors	1 : No Growt	100	49	0.385	0.002	0.001	0.08	0.02
3		48 Bay Doors	1 : No Growt	100	48	0.393	0.004	0.002	0.20	0.06
4		47 Bay Doors	1 : No Growt	100	47	0.402	0.007	0.002	0.34	0.11
5		46 Bay Doors	1 : No Growt	100	46	0.411	0.009	0.004	0.44	0.12
6		45 Bay Doors	1 : No Growt	100	45	0.420	0.016	0.009	0.74	0.18
7		44 Bay Doors	1 : No Growt	100	44	0.429	0.020	0.010	0.93	0.22
8		43 Bay Doors	1 : No Growt	100	43	0.438	0.026	0.012	1.38	0.27
9		42 Bay Doors	1 : No Growt	100	42	0.449	0.038	0.018	1.73	0.34
10		41 Bay Doors	1 : No Growt	100	41	0.459	0.050	0.025	2.01	0.44
11		40 Bay Doors	1 : No Growt	100	40	0.472	0.069	0.037	2.75	0.64
12		39 Bay Doors	1 : No Growt	100	39	0.483	0.093	0.053	3.59	0.77
13		38 Bay Doors	1 : No Growt	100	38	0.494	0.111	0.069	4.38	1.02
14		37 Bay Doors	1 : No Growt	100	37	0.507	0.134	0.079	5.15	1.12
15		36 Bay Doors	1 : No Growt	100	36	0.524	0.168	0.106	6.23	1.43
16		35 Bay Doors	1 : No Growt	100	35	0.536	0.200	0.137	7.17	1.59
17		34 Bay Doors	1 : No Growt	100	34	0.548	0.248	0.181	8.62	1.92
18		33 Bay Doors	1 : No Growt	100	33	0.560	0.291	0.219	9.63	2.31
19		32 Bay Doors	1 : No Growt	100	32	0.575	0.353	0.275	11.34	2.39
20		31 Bay Doors	1 : No Growt	100	31	0.586	0.415	0.330	13.13	2.80
21		30 Bay Doors	1 : No Growt	100	30	0.596	0.534	0.438	16.32	3.39

Using the data from Process Analyzer expected growth, we used Excel to graph the maximum queue time in minutes of outbound and inbound trucks vs. the number of the bay doors. As before, the outbound trucks have the highest maximum queue time. The graph shows us a similar shape as with the 20% growth rate. This confirms to expect a diminishing marginal return for each additional bay door we add (refer to Figure 15 – Max Queue Time vs. Number of Bay Doors for Expected Growth).

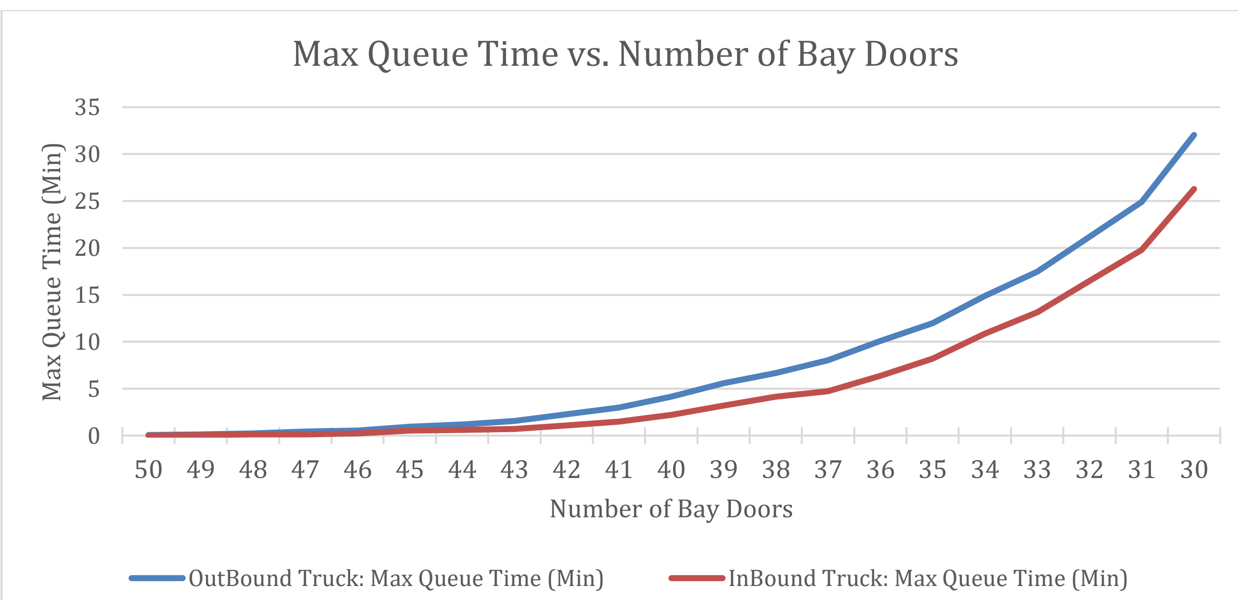

Figure 15 – Max Queue Time vs. Number of Bay Doors for Expected Growth

4.3 PARKING

According to *Dock Planning Standards* by Nova Technology, “If expected trucks are longer than 40 ft, increase the apron space proportionately.” (4). When determining the square footage for the truck parking lock, which will be located directly behind the warehouse in front of the bay doors, the apron space will be adjusted considering the longest truck entering lot will be 53 feet. Therefore, the apron space needed to occupy 44 bay doors with 12-foot center spacing, will be 159 feet ((53’/40’) * 120ft = 159’). The parking lot will be comprised of domestic and international trailers. Domestic trailers will be parked at a maximum of one day while an international trailer will be parked up to five days. At a maximum on any given day, there will be 33 FTL’s daily, and average of 70 LTL shipments totaling 103 domestic parking spaces for trailers, which generally stay on average 1 day. Similarly, there will be 55 parking spaces need for international trailers due to the facility averaging 11 international trailers per day, which stay on average five days. With this in mind, there will be 3 rows of 53 parking spaces available for domestic and international trailers (158 total trucks/3 rows = 53 parking spaces per row).

In order for the trucks to have sufficient maneuvering space, the appropriate apron space will be calculated for the parking lot, as the lot will be adjacent to the bay door apron space. Using the same apron space for the bay doors, 12-foot center spacing and 53-foot trailer size, the apron space for lot will be added by simply adding an additional 53 foot to the 159-foot apron space to accommodate the first row of parking spaces. Directly behind the first row of parking spaces will be the second row of spaces, as the two parking rows will be facing away from each other. As the second row of parking spaces are 53 feet, an additional 159 feet of apron space will be included along with an extra 53 feet to accommodate the third row of parking spaces that will face the second row. The total length of the lot will be 424 feet (53’ (2) + 159’ (2) = 424 feet). With 8.5 feet of standard width trailers, 12-foot center spacing between each trailer, and 53 trailer parking spaces, a total width for the lot will be 658.5 feet ((52 spaces between trucks * 12’ spacing) + (2) 4.25’ of trailer length from each side = 658.5’). Therefore, the total square footage of the lot will be 279,204 sq. ft. (424’ length * 658.5’ width = 279,204 sq. ft.), shown in Figure 16 (refer to Figure 16 – Parking Lot).

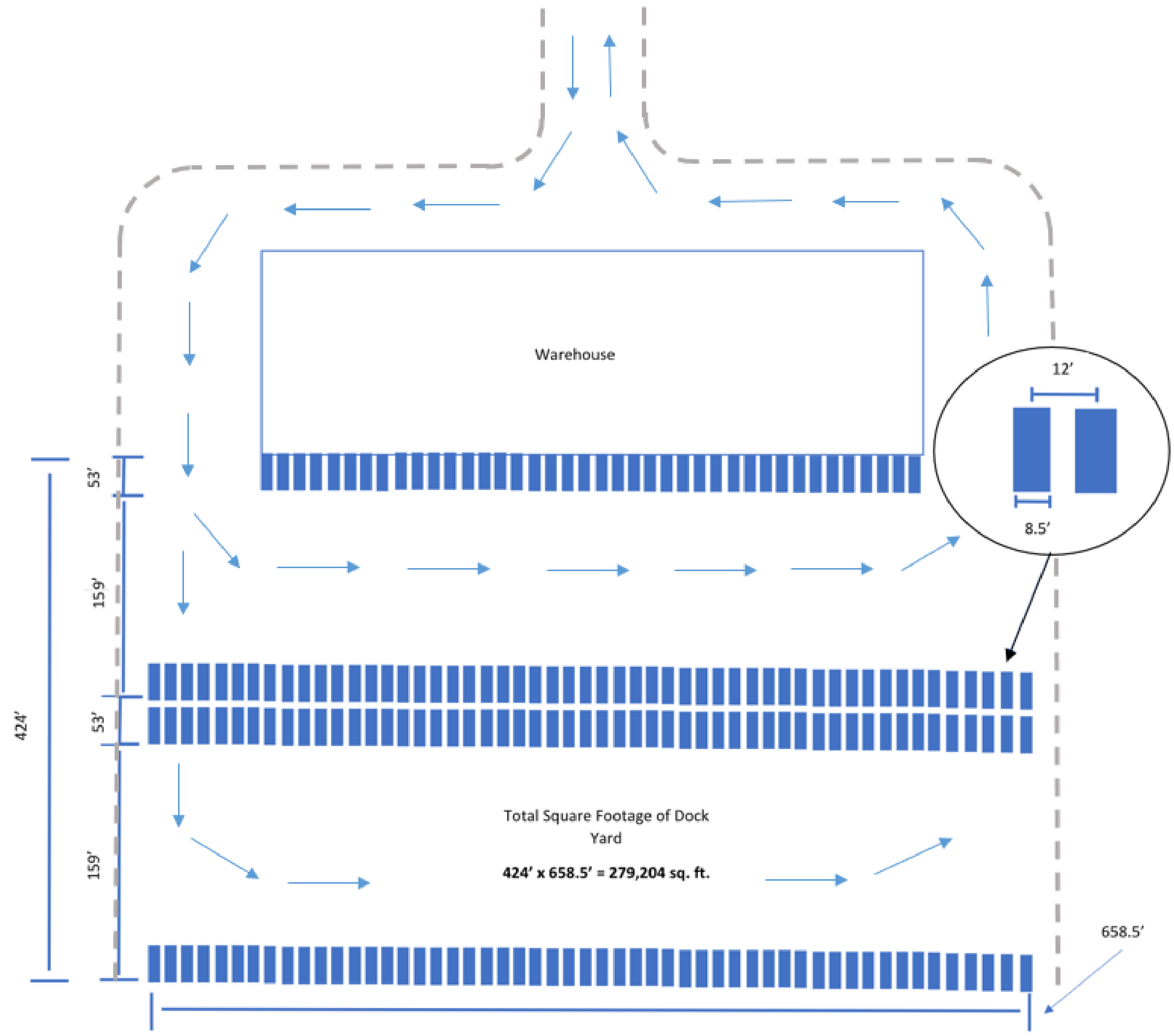

Figure 16 – Parking Lot

4.3.1 Total Square Footage Required

In order to gather the total square footage needed for the storage facility, we not only need the inventory storage space required, but we also need to account for square footage from the staging areas for inbound and outbound loading and unloading, aisle space, as well as the accessory lines the company wishes to implement. First, the company provided the amount of square footage they use for one of their current accessory lines which is 65,000 square ft. They also wish to have an additional accessory line for another product. Therefore, we doubled the square footage to 130,000 square ft. needed for two accessory lines. The accessory line's 130,000 square footage will be added to both the baseline and the alternative growth design without any differences between the two per request of the company.

Based on our simulation, the optimal amount of bay doors is 44, which we have selected to space 12ft center to center, which is explained in the parking and simulation section. Since the staging area needs to be 53 ft. in length, plus a 4-foot zone between the staging area and bay door to stage pickups for outbound trucks, the staging area needed to be (44*12) ft. * (53+4) ft., which comes to 30,096 sq. ft. of space for staging. The total facility square footage necessary was found by adding up the necessary square footage of accessory lines, staging, inventory space, aisle space required, and the exterior parking (refer to Table 17 – Total Sq. Footage).

Table 17 – Total Sq. Footage

TOTAL Sq Footage	BASELINE	20% GROWTH
accessory lines	130,000	130,000
staging	30,096	30,096
inventory space	138,903	150,161
aisle space	244,181	265,843
exterior parking	279,204	279,204
TOTAL:	822,384	855,304

CHAPTER 5: ECONOMIC ANALYSIS

5.1 ECONOMIC ANALYSIS

The manufacturing company has a budgeted a cost of $47.5 million. We used information on Market Watch to find the pretax income as well as the taxes the company paid to calculate their effective tax rate. We assumed a 12% Minimum Acceptable Rate of Return (MARR) (Refer on Table 14 – Background Information).

5.1.1 Background Information on the Company

Displayed below is the background information based on the company. The assumed MARR, Pretax Income, Income Tax, Effective Tax Rate, and Building cost are all included in Table 16 (refer to Table 18 – Background Information).

Table 18 - Background Information

Assumed MARR	Redacted
Pretax Income	Redacted
Income Tax	Redacted
Effective Tax Rate	Redacted
Building Cost	$ 47,500,000

5.1.2 No Depreciation

The company will make the equivalent present worth of their money back by 2026 at the assumed 12% MARR. By 2032, they should have an extra $15.92 million in present worth money (refer to Table 19 – No Depreciation). The company without including the calculations for MARR expects to make their money back by 2024. We decided to find the Internal Rate of Return (IRR). Both before and after taxes, the IRR is the same. We expected this as the after-tax cash flow is proportional to the before tax cash flow. The company will get their money back by 2024 with a low IRR of 1.71% (refer to Table 20 – No Depreciation IRR).

Table 19 – No Depreciation

Year	Cash Flow	After Tax Cash Flow	Present Worth @ 12% MARR	Cumulative Present Worth @ 12% MARR
19	-4.50	-3.42	-3.05	-3.05
20	-19.50	-14.82	-11.81	-14.86
21	-14.50	-11.02	-7.84	-22.71
22	18.40	13.98	8.88	-13.82
23	10.90	8.28	4.70	-9.12
24	10.90	8.28	4.20	-4.93
25	10.90	8.28	3.75	-1.18
26	10.90	8.28	3.34	2.17
27	10.90	8.28	2.99	5.15
28	10.90	8.28	2.67	7.82
29	10.90	8.28	2.38	10.20
30	10.90	8.28	2.13	12.32
31	10.90	8.28	1.90	14.22
32	10.90	8.28	1.69	15.92

Table 20 – No Depreciation IRR

Year	Cash Flow	After Tax Cash Flow
19	-4.50	-3.42
20	-19.50	-14.82
21	-14.50	-11.02
22	18.40	13.98
23	10.90	8.28
24	10.90	8.28
IRR	1.71%	1.71%

5.1.3 Depreciation

Depending upon the type of depreciation allowed, the company will use either straight line depreciation or 150% declining balance depreciation that switches to straight line depreciation. If allowed, the 150% declining balance with straight line switch is the preferred method. This method allows the company to depreciate the asset thereby recovering their money faster.

5.1.3.1 Straight Line Depreciation

Using straight line depreciation, the company will again make the equivalent present worth of their money back by 2026 at the assumed 12% MARR. By 2032, they should have an extra $17.15 million in present worth money (refer to Table 21 – Straight Line Depreciation). We decided to find the IRR including the calculations for depreciation. The before tax IRR is the same as with no depreciation, but the after-tax IRR is higher. This is because including depreciation lowers the amount in taxes they will have to pay. After taxes, the company will get their money back by 2024 with an IRR of 2.84% (refer to Table 22 – Straight Line Depreciation IRR).

Table 21 – Straight Line Depreciation

Year	Cash Flow	Depreciation	After Tax Cash Flow	Present Worth @ 12% MARR	Cumulative Present Worth @ 12% MARR
19	-4.50	0.00	-3.42	-3.05	-3.05
20	-19.50	0.00	-14.82	-11.81	-14.86
21	-14.50	0.00	-11.02	-7.84	-22.71
22	18.40	1.22	14.27	9.07	-13.63
23	10.90	1.22	8.57	4.87	-8.77
24	10.90	1.22	8.57	4.34	-4.43
25	10.90	1.22	8.57	3.88	-0.55
26	10.90	1.22	8.57	3.46	2.92
27	10.90	1.22	8.57	3.09	6.01
28	10.90	1.22	8.57	2.76	8.77
29	10.90	1.22	8.57	2.46	11.23
30	10.90	1.22	8.57	2.20	13.43
31	10.90	1.22	8.57	1.97	15.40
32	10.90	1.22	8.57	1.75	17.15

Table 22 – Straight Line Depreciation IRR

Year	CashFlow	After Tax Cash Flow
19	-4.50	-3.42
20	-19.50	-14.82
21	-14.50	-11.02
22	18.40	14.27
23	10.90	8.57
24	10.90	8.57
IRR	1.71%	2.84%

5.1.3.2 150% Declining Balance Depreciation

Using 150% declining balance depreciation, the company will again make the equivalent present worth of their money back by 2026 at the assumed 12% MARR, but the company will be close in 2025. By 2032, they should have an extra $17.52 million in present worth money (refer to Table 23 – Declining Balance Depreciation). After 2032, they will need to switch to the straight-line depreciation method because straight line depreciates a larger amount at that point. Starting in 2033, the company will have 1.22 million each year until the asset is fully depreciated (refer to Table 23 – Declining Balance Depreciation).

We again found the IRR including the calculations for depreciation. The before tax IRR is the same as both no depreciation and straight-line depreciation, but the after-tax IRR is higher than both. The 150% declining balance method depreciates faster than the straight-line method further lowering the immediate amount in taxes the company will have to pay. After taxes, the company will get their money back by 2024 with an IRR of 3.33% (refer to Table 24 – Declining Balance Depreciation IRR).

Table 23 – Declining Balance Depreciation

Year	Cash Flow	Depreciation	After Tax Cash Flow	Present Worth @ 12% MARR	Cumulative Present Worth @ 12% MARR
19	-4.50	0.00	-3.42	-3.05	-3.05
20	-19.50	0.00	-14.82	-11.81	-14.86
21	-14.50	0.00	-11.02	-7.84	-22.71
22	18.40	1.83	14.42	9.16	-13.54
23	10.90	1.76	8.70	4.94	-8.60
24	10.90	1.69	8.69	4.40	-4.20
25	10.90	1.62	8.67	3.92	-0.28
26	10.90	1.56	8.66	3.50	3.22
27	10.90	1.50	8.64	3.12	6.33
28	10.90	1.44	8.63	2.78	9.11
29	10.90	1.39	8.62	2.48	11.59
30	10.90	1.33	8.60	2.21	13.80
31	10.90	1.28	8.59	1.97	15.77
32	10.90	1.23	8.58	1.76	17.52

Table 24 – Declining Balance Depreciation IRR

Year	Cash Flow	After Tax Cash Flow
19	-4.50	-3.42
20	-19.50	-14.82
21	-14.50	-11.02
22	18.40	14.42
23	10.90	8.70
24	10.90	8.69
IRR	1.71%	3.33%

5.1.4 Depreciation Method Comparison

We graphed the cumulative present worth in millions of dollars over time overlaying both types of depreciations and the no depreciation. Depreciation starts in 2022. The graph shows that depreciation brings in more present worth money for the company with the 150% declining balance method proving slightly superior to straight line depreciation (refer to Figure 17 – Cumulative Present Worth Money Over Time).

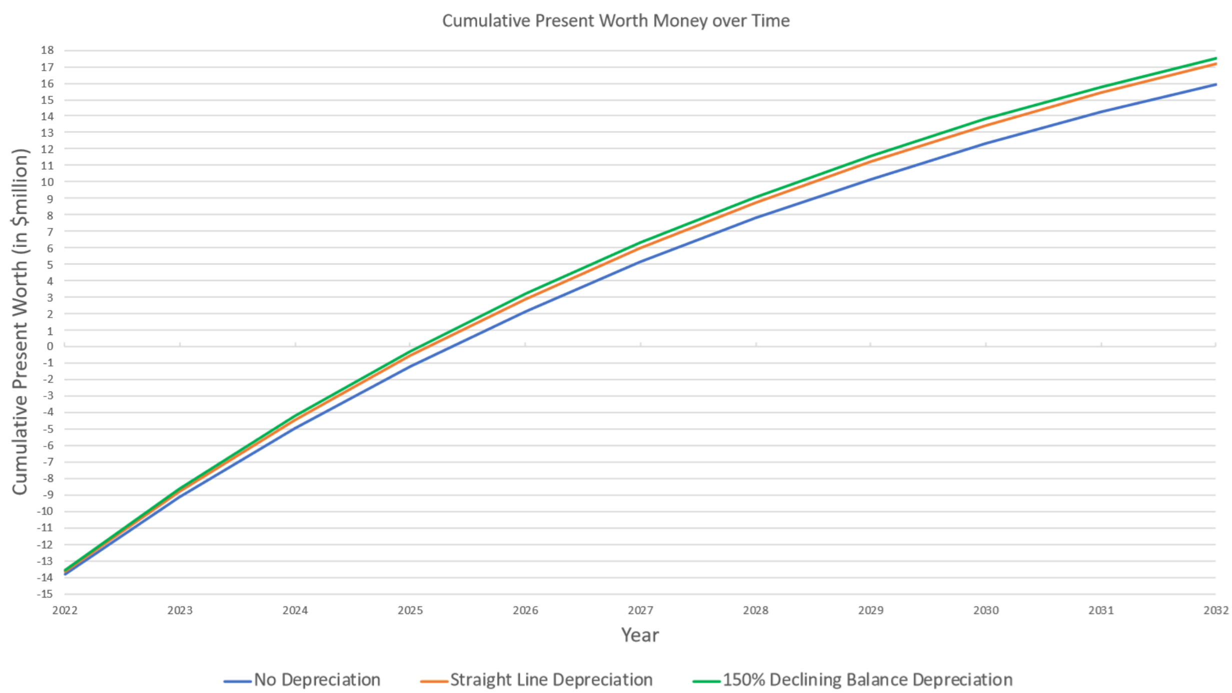

Figure 17 – Cumulative Present Worth Money Over Time

CHAPTER 6: FINDINGS AND RECOMMENDATIONS

6.1 RESULTS AND DISCUSSIONS

The company needs 44 bay doors in its facility. The exterior layout needs to be able to handle 158 trailers. It will have 3 rows of 53 parking lots for a combined 159 parking spots. If designing the facility for expected growth, the entire facility will require 822,384 square feet of land. If designing the facility for 20% growth, the entire facility will require 855,304 square feet of land. The project is economically justified at the expected building costs and cashflows with a 12% MARR. Using no depreciation, straight line depreciation, or 150% declining balance depreciation, the company will regain their present worth money by 2026.

6.2 CONCLUSIONS AND RECOMMENDTIONS

The company will not be able to use the land they currently own for either expected growth or 20% growth. They will need to purchase new land to build their new facility capable of handling maximum operations. Assuming the initial costs stay similar, the company is still economically justified in building this facility using the assumed resulting cashflows and the assumed 12% MARR. If the company keeps the initial costs from raising more than $2.92 million than their initial estimates, utilizing either depreciation will result in them breaking even in present worth money within 7 years. Throughout the course of this project, our group has achieved being able to determine facility dimensions, design the layout, perform economic analysis, account for growth factors, consider an expansion for the accessory line, reduce transportation costs, and produce a design for flow of products. We have been given the privilege to learn much more about designing a facility and why each aspect put into the design is crucial in creating an effective layout. Some future improvements we hope for next time is to create more bathrooms and break rooms for the facility. Both are very good additions to any type of building.

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APPENDICES:

APPENDIX A: ACKNOWLEDGEMENTS

The SMART Flow Design Team would like to express our appreciation to all those who provided us with help on this report. We give a special gratitude to our senior design advisor, Dr. Khalid, whose contributions helped coordinate the project to its fullest capability. Dr. Khalid is an Associate Professor in the Department of Industrial and Systems Engineering. Secondly, we would also like to acknowledge with much appreciation the manufacturing company's team for all of their help in providing direction, suggestions, and all of the initial data used. Lastly, we extend our gratitude to both Dr. Keyser and Dr. Esmaeili, who both provided their insight and help in this project. Dr. Keyser and Dr. Esmaeili are both Assistant Professors in the Department of Industrial and Systems Engineering.

APPENDIX B: CONTACT INFORMATION (STUDENTS AND ADVISOR CONTACTS)

Table 25 - Contact Information

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APPENDIX C: DATA

1C. Crate Dimensions

Table 26 – Crate Dimensions (Manufacturing Company)

Prod Line Name	Prod Line Num	Model Year	True Model	Case Pack Factor Qty	Case Length Inch	Case Width Inch	Case Height Inch	Case Weight Pound	Vol Cubic F
Redacted					31.91	77.38	42.13	500.43	52.90
					100.96	56.84	44.87	1023.42	128.94
					19.95	24.98	22.15	124.49	7.56
					38.83	39.99	32.68	341.62	14.22
					50.63	107.25	42.25	737.49	69.35
					28.13	79.98	44.40	377.24	61.02
					51.20	64.74	33.86	516.99	64.15
					125.52	79.00	63.77	1539.33	217.29
					32.98	37.27	21.54	197.31	21.90
					85.68	79.70	45.30	802.48	146.19

2C. Production Data (Plant)

Table 27 – Production Data A (Manufacturing Company)

		Jan-19			Feb-19			Mar-19		
Product Line	Source	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory
Redacted		1798	1486	**312**	1053	1100	**265**	1029	1027	**267**
		546	469	**77**	376	389	**64**	321	325	**60**
		1787	1372	**415**	1640	1614	**441**	554	790	**205**
		626	**440**	**186**	430	434	**182**	320	356	**146**
	20days	89.9	74.3	15.6	52.65	55	13.25	51.45	51.35	13.35
		27.3	23.45	3.85	18.8	19.45	3.2	16.05	16.25	3
		89.35	68.6	20.75	82	80.7	22.05	27.7	39.5	10.25
		31.3	22	9.3	21.5	21.7	9.1	16	17.8	7.3
	% distribution	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference
	1.50	89.9	111.45	-21.55	52.65	82.5	-29.85	51.45	77.1	-25.65
	1.25	89.9	92.875	-2.975	52.65	68.75	-16.1	51.45	64.25	-12.8
	1.00	89.9	74.3	15.6	52.65	55.00	-2.35	51.45	51.4	0.05
	0.75	89.9	55.725	34.175	52.65	41.25	11.4	51.45	38.55	12.9
	0.50	89.9	37.15	52.75	52.65	27.5	25.15	51.45	25.7	25.75
	1.50	27.3	35.25	-7.95	18.8	29.25	-10.45	16.05	24.45	-8.4
Tuesday	1.25	27.3	29.375	-2.075	18.8	24.375	-5.575	16.05	20.375	-4.325
Wednesday	1.00	27.3	23.5	3.8	18.8	19.5	-0.7	16.05	16.3	-0.25
Thursday	0.75	27.3	17.625	9.675	18.8	14.625	4.175	16.05	12.225	3.825
Friday	0.50	27.3	11.75	15.55	18.8	9.75	9.05	16.05	8.15	7.9
Redacted										
	1.50	89.35	102.9	-13.55	82	121.05	-39.05	27.7	59.25	-31.55
Tuesday	1.25	89.35	85.75	3.6	82	100.875	-18.875	27.7	49.375	-21.675
Wednesday	1.00	89.35	68.6	20.75	82	80.7	1.3	27.7	39.5	-11.8
Thursday	0.75	89.35	51.45	37.9	82	60.525	21.475	27.7	29.625	-1.925
Friday	0.50	89.35	34.3	55.05	82	40.35	41.65	27.7	19.75	7.95
Redacted										
	1.50	31.3	33	-1.7	21.5	32.55	-11.05	16	26.7	-10.7
Tuesday	*1.25*	31.3	27.5	3.8	21.5	*27.125*	-5.625	16	22.25	-6.25
Wednesday	1.00	31.3	22	9.3	21.5	21.7	-0.2	16	17.8	-1.8
Thursday	0.75	31.3	16.5	14.8	21.5	16.275	5.225	16	13.35	2.65
Friday	0.50	31.3	11	20.3	21.5	10.85	10.65	16	8.9	7.1

Table 28 – Production Data B (Manufacturing Company)

Apr-19			May-19			Jun-19			Jul-19		
Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory
561	613	**215**	1861	1580	**496**	1361	1510	**347**	2512	2282	**577**
243	245	**58**	263	265	**56**	274	272	**58**	364	334	**88**
151	263	**93**	88	130	**51**	0	33	**18**	491	316	**193**
515	466	**195**	240	307	**128**	310	310	**128**	297	301	**124**
28.05	30.65	10.75	93.05	79	24.8	68.05	75.5	17.35	125.6	114.1	28.85
12.15	12.25	2.9	13.15	13.25	2.8	13.7	13.6	2.9	18.2	16.7	4.4
7.55	13.15	4.65	4.4	6.5	2.55	0	1.65	0.9	24.55	15.8	9.65
25.75	23.3	9.75	12	15.35	6.4	15.5	15.5	6.4	14.85	15.05	6.2
daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference
28.05	46.05	-18.00	93.05	118.5	-25.45	68.05	113.25	-45.20	125.6	171.15	-45.55
28.05	38.375	-10.33	93.05	98.75	-5.7	68.05	94.375	-26.33	125.6	142.625	-17.025
28.05	30.7	-2.65	93.05	79	14.05	68.05	75.5	-7.45	125.6	114.1	11.5
28.05	23.025	5.03	93.05	59.25	33.8	68.05	56.625	11.43	125.6	85.575	40.025
28.05	15.35	12.70	93.05	39.5	53.55	68.05	37.75	30.30	125.6	57.05	68.55
12.15	18.45	-6.30	13.15	19.95	-6.8	13.7	20.4	-6.70	18.2	25.05	-6.85
12.15	15.375	-3.23	13.15	16.63	-3.475	13.7	17	-3.30	18.2	20.875	-2.675
12.15	12.3	-0.15	13.15	13.30	-0.15	13.7	13.6	0.10	18.2	16.7	1.5
12.15	9.225	2.93	13.15	9.98	3.175	13.7	10.2	3.50	18.2	12.525	5.675
12.15	6.15	6.00	13.15	6.65	6.5	13.7	6.8	6.90	18.2	8.35	9.85
7.55	19.8	-12.25	4.4	9.75	-5.35	0	2.475	-2.48	24.55	23.7	0.85
7.55	16.5	-8.95	4.4	8.13	-3.725	0	2.0625	-2.06	24.55	19.75	4.8
7.55	13.2	-5.65	4.4	6.50	-2.1	0	1.65	-1.65	24.55	15.8	8.75
7.55	9.9	-2.35	4.4	4.88	-0.475	0	1.2375	-1.24	24.55	11.85	12.7
7.55	6.6	0.95	4.4	3.25	1.15	0	0.825	-0.83	24.55	7.9	16.65
25.75	34.95	-9.20	12	23.10	-11.1	15.5	23.25	-7.75	14.85	22.575	-7.725
25.75	29.125	-3.38	12	19.25	-7.25	15.5	19.375	-3.88	14.85	18.8125	-3.9625
25.75	23.3	2.45	12	15.40	-3.4	15.5	15.5	0.00	14.85	15.05	-0.2
25.75	17.475	8.28	12	11.55	0.45	15.5	11.625	3.88	14.85	11.2875	3.5625
25.75	11.65	14.10	12	7.70	4.3	15.5	7.75	7.75	14.85	7.525	7.325

Table 29 – Production Data C (Manufacturing Company)

Sep-19			Oct-19			Nov-19			Dec-19		
Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory
1646	1640	**521**	790	958	**353**	1008	979	**382**	1002	677	**707**
428	409	**79**	443	443	**79**	253	265	**67**	236	166	**137**
1590	1286	**822**	1540	1410	**952**	1317	1267	**1002**	1197	1121	**1078**
120	161	**63**	378	312	**129**	218	211	**136**	92	106	**122**
82.3	82	26.05	39.5	47.9	17.65	50.4	48.95	19.1	50.1	33.85	35.35
21.4	20.45	3.95	22.15	22.15	3.95	12.65	13.25	3.35	11.8	8.3	6.85
79.5	64.3	41.1	77	70.5	47.6	65.85	63.35	50.1	59.85	56.05	53.9
6.00	8.05	3.15	18.9	15.6	6.45	10.9	10.55	6.8	4.6	5.3	6.1
daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference
82.3	123	-40.7	39.5	71.85	-32.35	50.4	73.425	-23.025	50.1	50.775	-0.675
82.3	102.5	-20.2	39.5	59.875	-20.375	50.4	61.1875	-10.7875	50.1	42.3125	7.7875
82.3	82	0.3	39.5	47.9	-8.4	50.4	48.95	1.45	50.1	33.85	16.25
82.3	61.5	20.8	39.5	35.925	3.575	50.4	36.7125	13.6875	50.1	25.3875	24.7125
82.3	41	41.3	39.5	23.95	15.55	50.4	24.475	25.925	50.1	16.925	33.175
21.4	30.675	-9.275	22.15	33.225	-11.075	12.65	19.875	-7.225	11.8	12.45	-0.65
21.4	25.5625	-4.1625	22.15	27.6875	-5.5375	12.65	16.5625	-3.9125	11.8	10.375	1.425
21.4	20.45	0.95	22.15	22.15	0	12.65	13.25	-0.6	11.8	8.3	3.5
21.4	15.3375	6.0625	22.15	16.6125	5.5375	12.65	9.9375	2.7125	11.8	6.225	5.575
21.4	10.225	11.175	22.15	11.075	11.075	12.65	6.625	6.025	11.8	4.15	7.65
79.5	96.45	-16.95	77	105.75	-28.75	65.85	95.025	-29.175	59.85	84.075	-24.225
79.5	80.375	-0.875	77	88.125	-11.125	65.85	79.1875	-13.3375	59.85	70.0625	-10.2125
79.5	64.3	15.2	77	70.5	6.5	65.85	63.35	2.5	59.85	56.05	3.8
79.5	48.225	31.275	77	52.875	24.125	65.85	47.5125	18.3375	59.85	42.0375	17.8125
79.5	32.15	47.35	77	35.25	41.75	65.85	31.675	34.175	59.85	28.025	31.825
6	12.075	-6.075	18.9	23.4	-4.5	10.9	15.825	-4.925	4.6	7.95	-3.35
6	10.0625	-4.0625	18.9	19.5	-0.6	10.9	13.1875	-2.2875	4.6	6.625	-2.025
6	8.05	-2.05	18.9	15.6	3.3	10.9	10.55	0.35	4.6	5.3	-0.7
6	6.0375	-0.0375	18.9	11.7	7.2	10.9	7.9125	2.9875	4.6	3.975	0.625
6	4.025	1.975	18.9	7.8	11.1	10.9	5.275	5.625	4.6	2.65	1.95

Table 30 – Production Data D (Manufacturing Company)

Jan-20			Feb-20			Mar-20			Apr-20		
Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory
2455	2469	**693**	1632	1833	**492**	1403	1465	**430**	1007	1046	**391**
698	698	**137**	285	346	**76**	228	226	**78**	295	290	**83**
2811	2868	**1021**	2780	2782	**1019**	590	1216	**393**	213	445	**161**
347	333	**136**	340	336	**140**	240	270	**110**	327	308	**129**
122.75	123.45	34.65	81.6	91.65	24.6	70.15	73.25	21.5	50.35	52.3	19.55
34.9	34.9	6.85	14.25	17.3	3.8	11.4	11.3	3.9	14.75	14.5	4.15
140.55	143.4	51.05	139.00	139.1	50.95	29.5	60.8	19.65	10.65	22.25	8.05
17.35	16.65	6.8	17	16.8	7	12	13.5	5.5	16.35	15.4	6.45
daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference
122.75	185.175	-62.425	81.6	137.475	-55.875	70.15	109.875	-39.725	50.35	78.45	-28.1
122.75	154.313	-31.5625	81.6	114.563	-32.9625	70.15	91.5625	-21.4125	50.35	65.375	-15.025
122.75	123.45	-0.7	81.6	91.65	-10.05	70.15	73.25	-3.1	50.35	52.3	-1.95
122.75	92.5875	30.1625	81.6	68.7375	12.8625	70.15	54.9375	15.2125	50.35	39.225	11.125
122.75	61.725	61.025	81.6	45.825	35.775	70.15	36.625	33.525	50.35	26.15	24.2
34.9	52.35	-17.45	14.25	25.95	-11.7	11.4	16.95	-5.55	14.75	21.75	-7
34.9	43.625	-8.725	14.25	21.625	-7.375	11.4	14.125	-2.725	14.75	18.125	-3.375
34.9	34.9	0	14.25	17.3	-3.05	11.4	11.3	0.1	14.75	14.5	0.25
34.9	26.175	8.725	14.25	12.975	1.275	11.4	8.475	2.925	14.75	10.875	3.875
34.9	17.45	17.45	14.25	8.65	5.6	11.4	5.65	5.75	14.75	7.25	7.5
140.55	215.1	-74.55	139	208.65	-69.65	29.5	91.2	-61.7	10.65	33.375	-22.725
140.55	179.25	-38.7	139	173.875	-34.875	29.5	76	-46.5	10.65	27.8125	-17.1625
140.55	143.4	-2.85	139	139.1	-0.1	29.5	60.8	-31.3	10.65	22.25	-11.6
140.55	107.55	33	139	104.325	34.675	29.5	45.6	-16.1	10.65	16.6875	-6.0375
140.55	71.7	68.85	139	69.55	69.45	29.5	30.4	-0.9	10.65	11.125	-0.475
17.35	24.975	-7.625	17	25.2	-8.2	12	20.25	-8.25	16.35	23.1	-6.75
17.35	20.8125	-3.4625	17	21	-4	12	16.875	-4.875	16.35	19.25	-2.9
17.35	16.65	0.7	17	16.8	0.2	12	13.5	-1.5	16.35	15.4	0.95
17.35	12.4875	4.8625	17	12.6	4.4	12	10.125	1.875	16.35	11.55	4.8
17.35	8.325	9.025	17	8.4	8.6	12	6.75	5.25	16.35	7.7	8.65

Table 31 – Production Data E (Manufacturing Company)

May-20			Jun-20			Jul-20			Aug-20		
Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory
1447	1422	**416**	2070	2024	**462**	2241	2156	**547**	1588	1655	**480**
689	657	**115**	688	678	**125**	452	491	**86**	476	467	**95**
52	161	**52**	0	40	**12**	592	380	**224**	814	633	**405**
130	185	**74**	268	243	**99**	347	315	**131**	130	187	**74**
72.35	71.1	20.8	103.5	101.2	23.1	112.05	107.8	27.35	79.4	82.75	24
34.45	32.85	5.75	34.4	33.9	6.25	22.6	24.55	4.3	23.8	23.35	4.75
2.6	8.05	2.6	0	2	0.6	29.6	19	11.2	40.7	31.65	20.25
6.5	9.25	3.7	13.4	12.15	4.95	17.35	15.75	6.55	6.5	9.35	3.7
daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference
72.35	106.65	-34.3	103.5	151.8	-48.3	112.05	161.7	-49.65	79.4	124.125	-44.725
72.35	88.875	-16.525	103.5	126.5	-23	112.05	134.75	-22.7	79.4	103.438	-24.0375
72.35	71.1	1.25	103.5	101.2	2.3	112.05	107.8	4.25	79.4	82.75	-3.35
72.35	53.325	19.025	103.5	75.9	27.6	112.05	80.85	31.2	79.4	62.0625	17.3375
72.35	35.55	36.8	103.5	50.6	52.9	112.05	53.9	58.15	79.4	41.375	38.025
34.45	49.275	-14.825	34.4	50.85	-16.45	22.6	36.825	-14.225	23.8	35.025	-11.225
34.45	41.0625	-6.6125	34.4	42.375	-7.975	22.6	30.6875	-8.0875	23.8	29.1875	-5.3875
34.45	32.85	1.6	34.4	33.9	0.5	22.6	24.55	-1.95	23.8	23.35	0.45
34.45	24.6375	9.8125	34.4	25.425	8.975	22.6	18.4125	4.1875	23.8	17.5125	6.2875
34.45	16.425	18.025	34.4	16.95	17.45	22.6	12.275	10.325	23.8	11.675	12.125
2.6	12.075	-9.475	0	3	-3	29.6	28.5	1.1	40.7	47.475	-6.775
2.6	10.0625	-7.4625	0	2.5	-2.5	29.6	23.75	5.85	40.7	39.5625	1.1375
2.6	8.05	-5.45	0	2	-2	29.6	19	10.6	40.7	31.65	9.05
2.6	6.0375	-3.4375	0	1.5	-1.5	29.6	14.25	15.35	40.7	23.7375	16.9625
2.6	4.025	-1.425	0	1	-1	29.6	9.5	20.1	40.7	15.825	24.875
6.5	13.875	-7.375	13.4	18.225	-4.825	17.35	23.625	-6.275	6.5	14.025	-7.525
6.5	11.5625	-5.0625	13.4	15.1875	-1.7875	17.35	19.6875	-2.3375	6.5	11.6875	-5.1875
6.5	9.25	-2.75	13.4	12.15	1.25	17.35	15.75	1.6	6.5	9.35	-2.85
6.5	6.9375	-0.4375	13.4	9.1125	4.2875	17.35	11.8125	5.5375	6.5	7.0125	-0.5125
6.5	4.625	1.875	13.4	6.075	7.325	17.35	7.875	9.475	6.5	4.675	1.825

Table 32 – Production Data F (Manufacturing Company)

Sep-20			Oct-20			Nov-20			Dec-20		
Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory
1281	1328	**433**	1073	1085	**421**	731	825	**327**	789	519	**597**
440	449	**86**	248	269	**65**	153	168	**50**	210	149	**111**
1020	864	**561**	1488	1201	**848**	1985	1583	**1250**	1703	1502	**1451**
20	68	**26**	20	34	**12**	30	27	**15**	20	17	**18**
64.05	66.4	21.65	53.65	54.25	21.05	36.55	41.25	16.35	39.45	25.95	29.85
22.00	22.45	4.3	12.4	13.45	3.25	7.65	8.4	2.5	10.5	7.45	5.55
51.00	43.2	28.05	74.4	60.05	42.4	99.25	79.15	62.5	85.15	75.1	72.55
1.00	3.4	1.3	1	1.7	0.6	1.5	1.35	0.75	1	0.85	0.9
daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference
64.05	99.6	-35.55	53.65	81.375	-27.725	36.55	61.875	-25.325	39.45	38.925	0.525
64.05	83	-18.95	53.65	67.8125	-14.1625	36.55	51.5625	-15.0125	39.45	32.4375	7.0125
64.05	66.4	-2.35	53.65	54.25	-0.6	36.55	41.25	-4.7	39.45	25.95	13.5
64.05	49.8	14.25	53.65	40.6875	12.9625	36.55	30.9375	5.6125	39.45	19.4625	19.9875
64.05	33.2	30.85	53.65	27.125	26.525	36.55	20.625	15.925	39.45	12.975	26.475
22	33.675	-11.675	12.4	20.175	-7.775	7.65	12.6	-4.95	10.5	11.175	-0.675
22	28.0625	-6.0625	12.4	16.8125	-4.4125	7.65	10.5	-2.85	10.5	9.3125	1.1875
22	22.45	-0.45	12.4	13.45	-1.05	7.65	8.4	-0.75	10.5	7.45	3.05
22	16.8375	5.1625	12.4	10.0875	2.3125	7.65	6.3	1.35	10.5	5.5875	4.9125
22	11.225	10.775	12.4	6.725	5.675	7.65	4.2	3.45	10.5	3.725	6.775
51	64.8	-13.8	74.4	90.075	-15.675	99.25	118.725	-19.475	85.15	112.65	-27.5
51	54	-3	74.4	75.0625	-0.6625	99.25	98.9375	0.3125	85.15	93.875	-8.725
51	43.2	7.8	74.4	60.05	14.35	99.25	79.15	20.1	85.15	75.1	10.05
51	32.4	18.6	74.4	45.0375	29.3625	99.25	59.3625	39.8875	85.15	56.325	28.825
51	21.6	29.4	74.4	30.025	44.375	99.25	39.575	59.675	85.15	37.55	47.6
1	5.1	-4.1	1	2.55	-1.55	1.5	2.025	-0.525	1	1.275	-0.275
1	4.25	-3.25	1	2.125	-1.125	1.5	1.6875	-0.1875	1	1.0625	-0.0625
1	3.4	-2.4	1	1.7	-0.7	1.5	1.35	0.15	1	0.85	0.15
1	2.55	-1.55	1	1.275	-0.275	1.5	1.0125	0.4875	1	0.6375	0.3625
1	1.7	-0.7	1	0.85	0.15	1.5	0.675	0.825	1	0.425	0.575

Table 33 – Production Data G (Manufacturing Company)

Jan-21			Feb-21			Mar-21			Apr-21		
Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory
2380	2371	**606**	1500	1673	**433**	1539	1519	**453**	860	963	**350**
868	824	**155**	323	399	**79**	219	231	**67**	126	144	**49**
3048	3315	**1184**	2966	3036	**1114**	524	1222	**416**	214	458	**172**
50	48	**20**	30	36	**14**	60	53	**21**	50	50	**21**
119	118.55	30.3	75	83.65	21.65	76.95	75.95	22.65	43	48.15	17.5
43.4	41.2	7.75	16.15	19.95	3.95	10.95	11.55	3.35	6.3	7.2	2.45
152.4	165.75	59.2	148.3	151.8	55.7	26.2	61.1	20.8	10.7	22.9	8.6
2.5	2.4	1	1.5	1.8	0.7	3	2.65	1.05	2.5	2.5	1.05
daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference
119	177.75	-58.75	75	125.475	-50.475	76.95	113.925	-36.975	43	72.225	-29.225
119	148.125	-29.125	75	104.563	-29.5625	76.95	94.9375	-17.9875	43	60.1875	-17.1875
119	118.5	0.5	75	83.65	-8.65	76.95	75.95	1	43	48.15	-5.15
119	88.875	30.125	75	62.7375	12.2625	76.95	56.9625	19.9875	43	36.1125	6.8875
119	59.25	59.75	75	41.825	33.175	76.95	37.975	38.975	43	24.075	18.925
43.4	61.8	-18.4	16.15	29.925	-13.775	10.95	17.325	-6.375	6.3	10.8	-4.5
43.4	51.5	-8.1	16.15	24.9375	-8.7875	10.95	14.4375	-3.4875	6.3	9	-2.7
43.4	41.2	2.2	16.15	19.95	-3.8	10.95	11.55	-0.6	6.3	7.2	-0.9
43.4	30.9	12.5	16.15	14.9625	1.1875	10.95	8.6625	2.2875	6.3	5.4	0.9
43.4	20.6	22.8	16.15	9.975	6.175	10.95	5.775	5.175	6.3	3.6	2.7
152.4	248.625	-96.225	148.3	227.7	-79.4	26.2	91.65	-65.45	10.7	34.35	-23.65
152.4	207.188	-54.7875	148.3	189.75	-41.45	26.2	76.375	-50.175	10.7	28.625	-17.925
152.4	165.75	-13.35	148.3	151.8	-3.5	26.2	61.1	-34.9	10.7	22.9	-12.2
152.4	124.313	28.0875	148.3	113.85	34.45	26.2	45.825	-19.625	10.7	17.175	-6.475
152.4	82.875	69.525	148.3	75.9	72.4	26.2	30.55	-4.35	10.7	11.45	-0.75
2.5	3.6	-1.1	1.5	2.7	-1.2	3	3.975	-0.975	2.5	3.75	-1.25
2.5	3	-0.5	1.5	2.25	-0.75	3	3.3125	-0.3125	2.5	3.125	-0.625
2.5	2.4	0.1	1.5	1.8	-0.3	3	2.65	0.35	2.5	2.5	0
2.5	1.8	0.7	1.5	1.35	0.15	3	1.9875	1.0125	2.5	1.875	0.625
2.5	1.2	1.3	1.5	0.9	0.6	3	1.325	1.675	2.5	1.25	1.25

Table 34 – Production Data H (Manufacturing Company)

May-21			Jun-21			Jul-21			Aug-21		
Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory	Production	Sales	Ending Inventory
1416	1353	**413**	2420	2265	**568**	2267	2279	**556**	1792	1785	**563**
597	541	**105**	859	827	**137**	603	623	**117**	611	602	**126**
149	227	**94**	0	68	**26**	476	310	**192**	1158	827	**523**
30	37	**14**	10	18	**6**	40	33	**13**	50	45	**18**
70.8	67.65	20.65	121	113.25	28.4	113.35	113.95	27.8	89.6	89.25	28.15
29.85	27.05	5.25	42.95	41.35	6.85	30.15	31.15	5.85	30.55	30.1	6.3
7.45	11.35	4.7	0	3.4	1.3	23.8	15.5	9.6	57.9	41.35	26.15
1.5	1.85	0.7	0.5	0.9	0.3	2	1.65	0.65	2.5	2.25	0.9
daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference	daily production	daily sales	end inv. Difference
70.8	101.475	-30.675	121	169.875	-48.875	113.35	170.925	-57.575	89.6	133.875	-44.275
70.8	84.5625	-13.7625	121	141.563	-20.5625	113.35	142.438	-29.0875	89.6	111.563	-21.9625
70.8	67.65	3.15	121	113.25	7.75	113.35	113.95	-0.6	89.6	89.25	0.35
70.8	50.7375	20.0625	121	84.9375	36.0625	113.35	85.4625	27.8875	89.6	66.9375	22.6625
70.8	33.825	36.975	121	56.625	64.375	113.35	56.975	56.375	89.6	44.625	44.975
29.85	40.575	-10.725	42.95	62.025	-19.075	30.15	46.725	-16.575	30.55	45.15	-14.6
29.85	33.8125	-3.9625	42.95	51.6875	-8.7375	30.15	38.9375	-8.7875	30.55	37.625	-7.075
29.85	27.05	2.8	42.95	41.35	1.6	30.15	31.15	-1	30.55	30.1	0.45
29.85	20.2875	9.5625	42.95	31.0125	11.9375	30.15	23.3625	6.7875	30.55	22.575	7.975
29.85	13.525	16.325	42.95	20.675	22.275	30.15	15.575	14.575	30.55	15.05	15.5
7.45	17.025	-9.575	0	5.1	-5.1	23.8	23.25	0.55	57.9	62.025	-4.125
7.45	14.1875	-6.7375	0	4.25	-4.25	23.8	19.375	4.425	57.9	51.6875	6.2125
7.45	11.35	-3.9	0	3.4	-3.4	23.8	15.5	8.3	57.9	41.35	16.55
7.45	8.5125	-1.0625	0	2.55	-2.55	23.8	11.625	12.175	57.9	31.0125	26.8875
7.45	5.675	1.775	0	1.7	-1.7	23.8	7.75	16.05	57.9	20.675	37.225
1.5	2.775	-1.275	0.5	1.35	-0.85	2	2.475	-0.475	2.5	3.375	-0.875
1.5	2.3125	-0.8125	0.5	1.125	-0.625	2	2.0625	-0.0625	2.5	2.8125	-0.3125
1.5	1.85	-0.35	0.5	0.9	-0.4	2	1.65	0.35	2.5	2.25	0.25
1.5	1.3875	0.1125	0.5	0.675	-0.175	2	1.2375	0.7625	2.5	1.6875	0.8125
1.5	0.925	0.575	0.5	0.45	0.05	2	0.825	1.175	2.5	1.125	1.375

3C. Sales Data

Table 35 – Sales Data A (Manufacturing Company)

Product Line	Product Division	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20
Redacted		540	576	864	774	576	702	828	792	738	700	1,026	938	409	567	841
		816	698	917	730	802	805	673	812	688	569	769	695	426	649	762
		298	340	299	415	432	378	393	258	414	339	350	353	251	346	664
		2,321	1,405	2,418	2,552	2,655	827	1	304	2,268	1,387	1,246	794	1,730	1,083	2,585
		3,332	4,021	5,555	4,495	5,820	5,843	4,737	4,105	4,517	5,352	3,925	4,698	3,502	4,225	5,837
		328	357	362	616	679	737	686	629	522	479	403	390	411	430	444
		8	7	7	5	4	2	2	26	24	32	28	28	36	36	36
		975	975	975	975	975	975	975	975	975	975	975	975	1,025	1,025	1,025

Table 36 – Sales Data B (Manufacturing Company)

Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21
817	666	655	819	745	689	823	902	941	437	547	803	814	580	610	792	841	751	1,008	1,118	1,042
746	736	789	693	870	621	526	823	633	711	644	535	655	679	655	695	1,051	428	485	759	696
894	552	445	355	395	741	515	667	539	564	599	540	608	646	976	530	594	717	557	749	582
2,737	2,826	952	0	326	1,953	1,888	1,420	934	1,595	1,017	2,523	2,819	2,964	943	42	1,735	1,539	1,445	1,412	497
4,723	6,115	6,139	4,978	4,314	4,747	5,624	4,124	4,936	3,688	4,449	6,146	4,973	6,440	6,465	5,242	4,543	4,998	5,922	4,343	5,198
490	555	671	631	559	464	447	381	369	344	357	409	452	514	626	584	499	400	394	311	297
34	24	23	23	24	33	37	38	40	39	39	38	34	25	24	24	26	34	39	40	41
1,025	1,025	1,025	1,025	1,025	1,025	1,025	1,025	1,025	1,053	1,053	1,053	1,053	1,053	1,053	1,053	1,053	1,053	1,053	1,053	1,053

4C. Receipts

Table 37 – Receipts A (Manufacturing Company)

Product Line Receipts	MFG Source	Product Division	% of receipts	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20
Redacted			18.4%	581	664	568	630	798	956	558	820	982	598	852	431	566	698	550
			31.5%	895	885	752	835	692	959	868	584	593	678	286	779	849	810	749
			37.0%	440	474	433	448	443	461	433	279	326	167	74	463	579	748	760
			60.0%	939	2,317	2,509	2,731	217	541	1,489	1,260	1,618	1,660	1,137	971	957	2,405	2,501
			100.0%	5,080	5,590	5,295	3,790	4,710	4,513	4,390	4,590	4,562	4,962	4,858	3,823	4,820	5,170	6,263
			18.9%	1,203	684	640	601	616	508	478	414	414	357	293	255	962	574	524
			0.8%	2	3	6	0	0	32	36	47	42	43	41	42	39	35	22
			11.2%	986	985	1,034	925	1,057	989	1,050	1,010	1,035	1,003	641	982	982	982	982

Table 38 – Receipts B (Manufacturing Company)

May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21
829	1,008	803	710	796	1,025	987	669	454	596	734	579	873	1,061	845	747	838	1,079	1,039	704
644	293	956	1,121	504	661	524	413	977	1,056	487	577	369	149	886	1,560	523	653	566	488
485	337	592	538	577	641	646	588	382	731	881	841	630	385	665	699	647	747	736	573
2,632	600	606	1,938	1,535	1,398	1,424	1,336	865	892	2,342	2,581	2,769	673	678	1,863	1,384	1,670	1,705	1,191
5,150	5,352	5,163	4,560	4,670	5,080	4,760	4,550	2,930	4,430	4,660	6,430	7,130	5,470	5,330	4,950	4,840	5,230	5,260	4,690
558	557	830	406	389	332	304	291	282	777	468	459	506	511	702	340	296	274	236	227
23	22	26	40	40	49	44	40	38	36	27	23	23	23	26	42	47	55	47	42
982	982	982	982	982	982	982	982	999	999	999	999	999	999	999	999	999	999	999	999

5C. Ending Inventory

Table 39 – Ending Inventory A (Manufacturing Company)

Product Line Ending Inventory	MFG Source	Product Division	Actual Ending Inventory Jan 2019	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20
Redacted			1,516	1,521	1,321	1,114	1,168	1,264	1,392	1,158	1,240	1,522	1,093	1,007	1,030	1,029	886	619
			747	945	913	935	968	855	1,141	1,196	1,092	1,117	1,027	618	971	1,171	1,219	1,222
			462	562	737	754	770	835	903	1,078	944	931	748	468	680	914	998	864
			1,632	1,166	1,065	1,022	1,098	489	1,029	2,214	1,206	1,438	1,852	2,194	1,435	1,309	1,130	894
			4,084	5,143	5,178	5,978	3,948	2,815	2,591	2,876	2,949	2,159	3,196	3,356	3,677	4,272	3,605	5,145
			1,415	2,261	2,583	2,606	2,529	2,408	2,230	2,079	1,971	1,906	1,860	1,763	1,607	2,138	2,268	2,302
			1,553	1,547	1,543	1,544	1,540	1,538	1,567	1,578	1,601	1,611	1,626	1,638	1,645	1,648	1,647	1,635
			4,206	4,218	4,229	4,288	4,239	4,321	4,335	4,411	4,446	4,506	4,535	4,201	4,158	4,115	4,072	4,029

Table 40 – Ending Inventory B (Manufacturing Company)

May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21
782	1,135	1,119	1,083	1,190	1,392	1,477	1,205	1,221	1,270	1,201	967	1,260	1,711	1,764	1,671	1,758	1,829	1,750	1,412
1,130	634	897	1,148	1,031	1,166	868	648	913	1,326	1,277	1,199	890	383	574	1,082	1,177	1,345	1,151	943
797	690	927	1,070	906	1,032	1,011	1,061	879	1,011	1,352	1,585	1,569	979	1,113	1,218	1,147	1,337	1,323	1,314
700	347	953	2,565	2,147	1,657	1,661	2,063	1,334	1,208	1,028	790	596	326	962	1,090	936	1,160	1,453	2,147
4,180	3,392	3,578	3,824	3,747	3,204	3,839	3,453	2,695	2,676	1,190	2,646	3,337	2,342	2,431	2,838	2,680	1,988	2,905	2,397
2,306	2,192	2,391	2,238	2,163	2,048	1,971	1,893	1,830	2,251	2,311	2,318	2,310	2,195	2,313	2,154	2,050	1,930	1,854	1,784
1,634	1,633	1,636	1,651	1,659	1,671	1,677	1,677	1,676	1,673	1,662	1,651	1,649	1,648	1,650	1,666	1,679	1,695	1,702	1,703
3,987	3,944	3,901	3,858	3,815	3,772	3,729	3,686	3,633	3,579	3,526	3,472	3,419	3,366	3,312	3,259	3,205	3,152	3,099	3,045

6C. Total Production

Table 41 – Total Production A (Manufacturing Company)

Product Line	MFG Source	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20
Redacted		2,536	3,157	3,607	3,086	3,422	4,337	5,198	3,032	4,455	5,336	3,248	4,630	2,344	3,075	3,792	2,988
		2,863	2,842	2,811	2,386	2,652	2,198	3,044	2,755	1,853	1,884	2,153	909	2,474	2,694	2,573	2,377
		931	1,190	1,280	1,169	1,210	1,198	1,246	1,170	755	880	450	200	1,252	1,565	2,022	2,055
		1,593	1,565	3,861	4,181	4,552	362	901	2,482	2,100	2,697	2,766	1,895	1,618	1,595	4,009	4,169
		4,084	5,080	5,590	5,295	3,790	4,710	4,513	4,390	4,590	4,562	4,962	4,858	3,823	4,820	5,170	6,263
		2,090	6,363	3,618	3,385	3,180	3,260	2,688	2,528	2,190	2,190	1,890	1,550	1,350	5,088	3,038	2,770
		1,098	204	408	690	0	24	3,980	4,484	5,894	5,280	5,424	5,076	5,280	4,892	4,388	2,754
		10,681	8,807	8,799	9,230	8,261	9,437	8,827	9,374	9,020	9,237	8,958	5,719	8,770	8,770	8,770	8,770

Table 42 – Total Production B (Manufacturing Company)

May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21
4,506	5,479	4,363	3,858	4,325	5,568	5,366	3,635	2,468	3,237	3,992	3,146	4,744	5,768	4,593	4,062	4,553	5,862	5,649	3,827
2,045	930	3,035	3,560	1,599	2,099	1,665	1,311	3,100	3,352	1,545	1,832	1,172	472	2,813	4,952	1,660	2,073	1,796	1,549
1,311	912	1,600	1,454	1,560	1,732	1,747	1,590	1,032	1,977	2,381	2,274	1,703	1,041	1,797	1,889	1,748	2,018	1,988	1,549
4,386	1,000	1,010	3,230	2,559	2,330	2,373	2,227	1,442	1,487	3,904	4,302	4,615	1,121	1,130	3,105	2,307	2,783	2,841	1,985
5,150	5,352	5,163	4,560	4,670	5,080	4,760	4,550	2,930	4,430	4,660	6,430	7,130	5,470	5,330	4,950	4,840	5,230	5,260	4,690
2,955	2,945	4,393	2,148	2,060	1,755	1,610	1,540	1,490	4,113	2,478	2,430	2,675	2,705	3,713	1,798	1,565	1,450	1,250	1,200
2,826	2,754	3,240	5,018	5,034	6,146	5,550	5,034	4,794	4,464	3,350	2,814	2,874	2,814	3,300	5,246	5,874	6,896	5,814	5,262
8,770	8,770	8,770	8,770	8,770	8,770	8,770	8,770	8,923	8,923	8,923	8,923	8,923	8,923	8,923	8,923	8,923	8,923	8,923	8,923

7C. Simulation Process

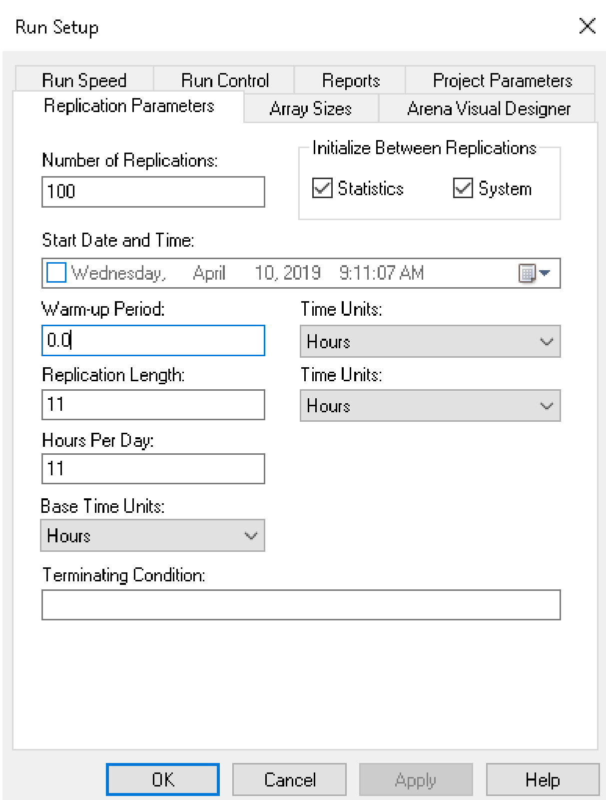

Figure 18 – Run Setup

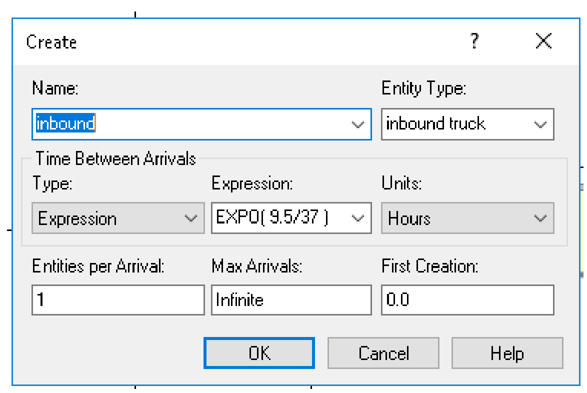

Figure 19 – Create

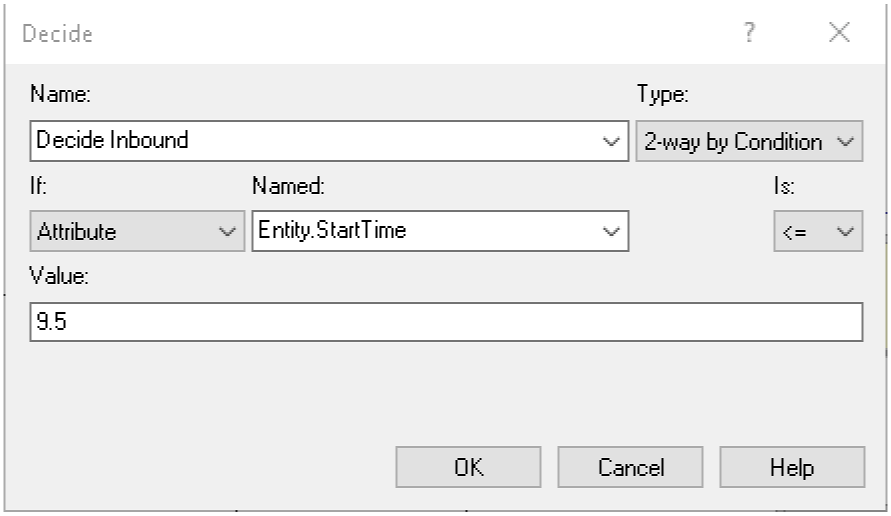

Figure 20 – Decide

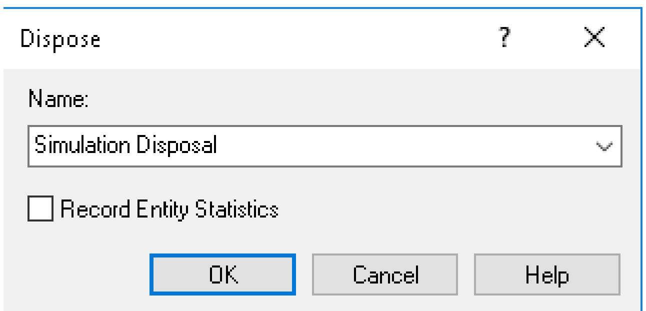

Figure 21 – Dispose

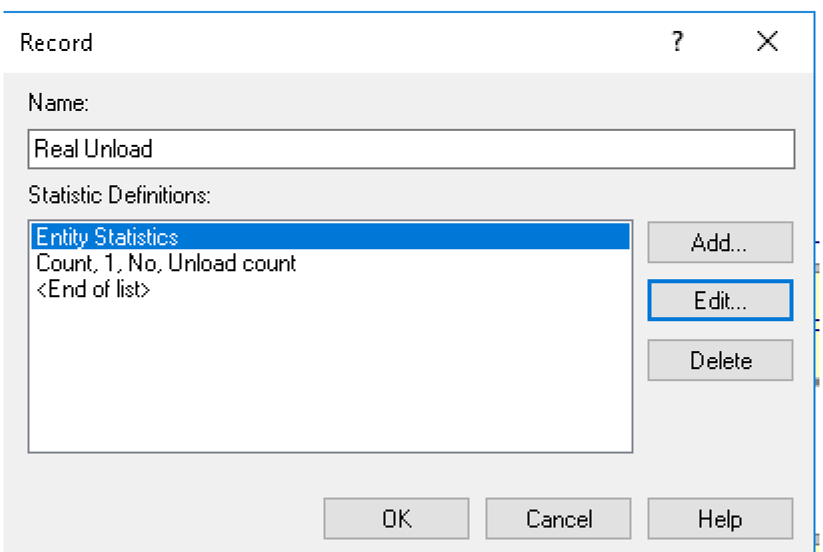

Figure 22 – Record

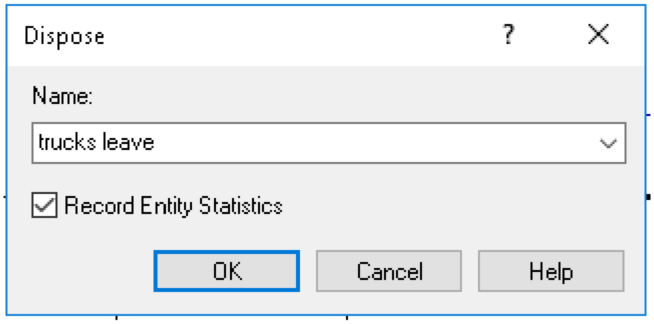

Figure 23 – Trucks Leave Dispose

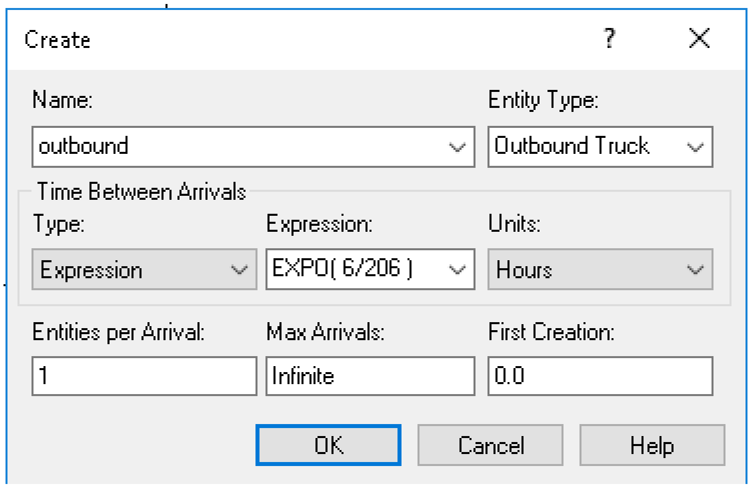

Figure 24 – Create Outbound

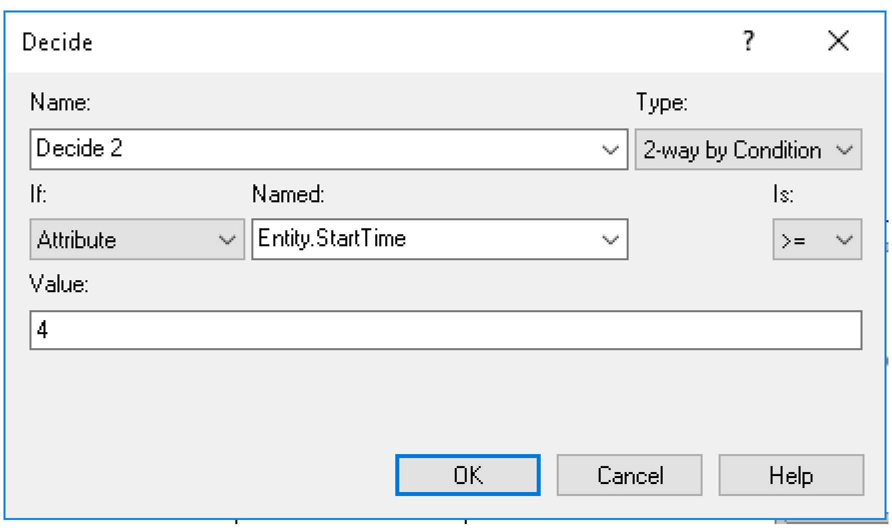

Figure 25 – Decide 2

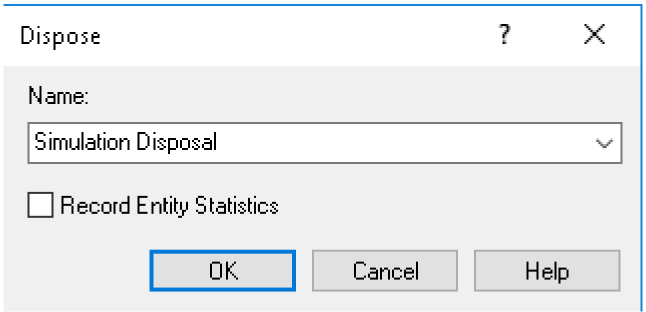

Figure 26– Simulation Disposal

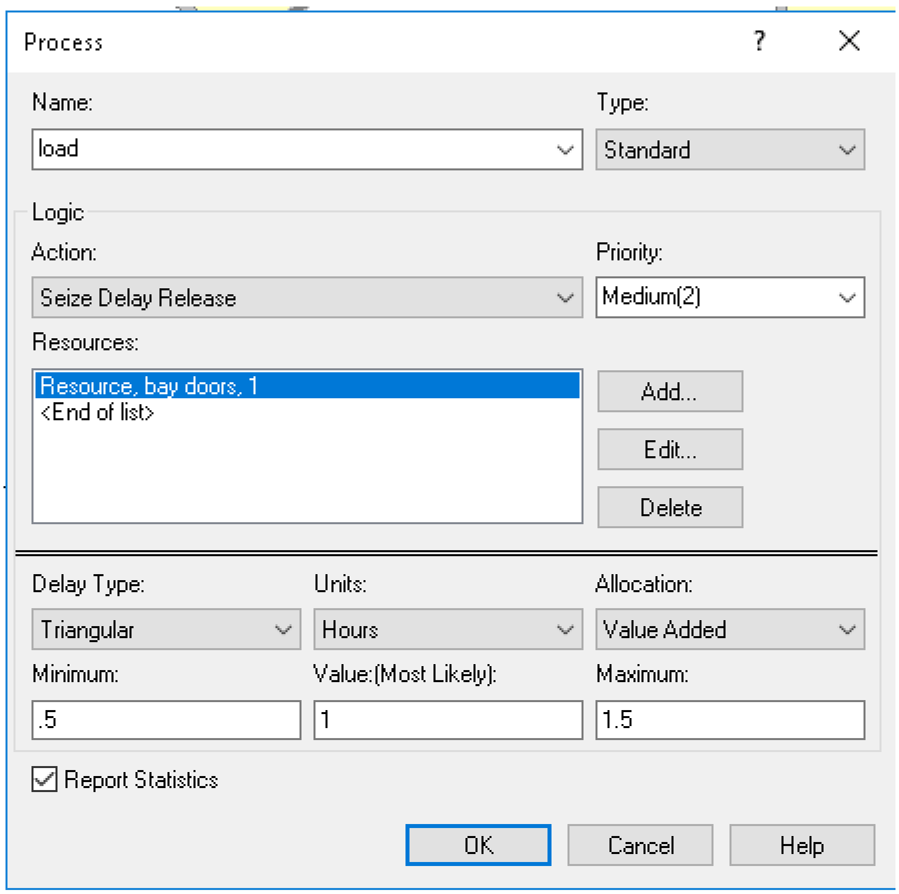

Figure 27 – Process

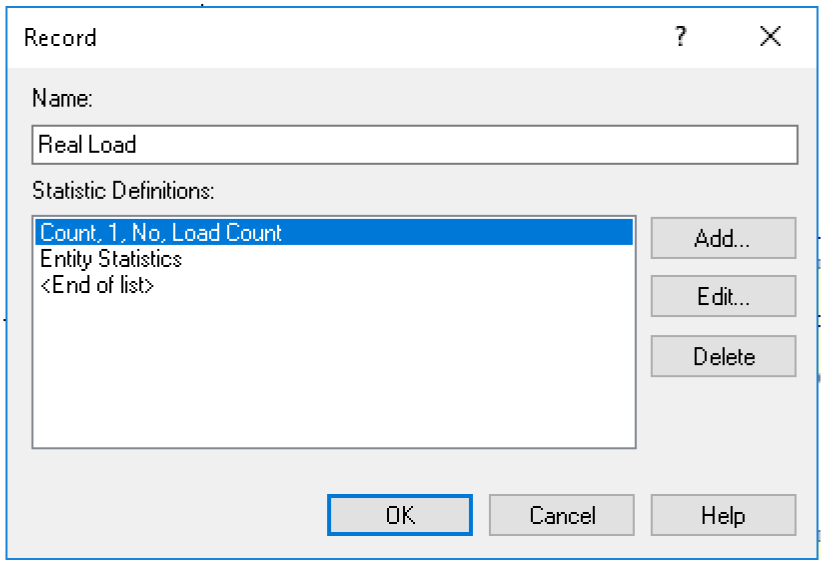

Figure 28 – Record 2

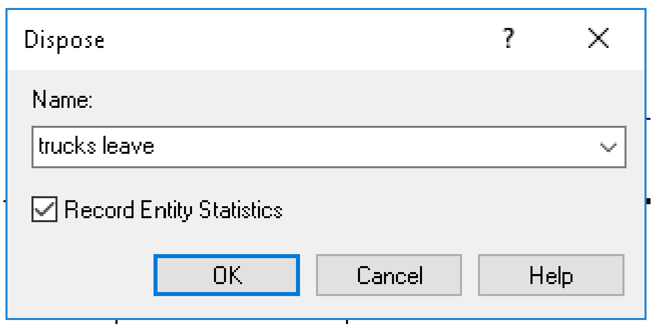

Figure 29 – Dispose 2

8C. <u>Economic Analysis</u>

Table 43 – No Depreciation Economic Calculations

No Depreciation														
							0.07		0.1		0.12		0.15	
Year	EOY	Outflow	InFlow	CashFlow	After Tax CF	Cum AFCF	PW @ 7%	Cum PW @ 7%	PW @ 10%	Cum PW @ 10%	PW @ 12%	Cum PW @ 12%	PW @ 15%	Cum PW @ 15%
19	1	-4.5	0	-4.5	-3.419	-3.419	-3.195	-3.195	-3.108	-3.108	-3.053	-3.053	-2.973	-2.973
20	2	-21.5	2	-19.5	-14.816	-18.235	-12.941	-16.136	-12.245	-15.353	-11.811	-14.864	-11.203	-14.176
21	3	-21.5	7	-14.5	-11.017	-29.252	-8.993	-25.129	-8.277	-23.630	-7.842	-22.706	-7.244	-21.420
22	4	0	18.4	18.4	13.980	-15.272	10.665	-14.464	9.549	-14.081	8.885	-13.821	7.993	-13.427
23	5	0	10.9	10.9	8.282	-6.990	5.905	-8.559	5.142	-8.939	4.699	-9.122	4.117	-9.309
24	6	0	10.9	10.9	8.282	1.292	5.518	-3.041	4.675	-4.264	4.196	-4.926	3.580	-5.729
25	7	0	10.9	10.9	8.282	9.573	5.157	2.117	4.250	-0.014	3.746	-1.180	3.113	-2.615
26	8	0	10.9	10.9	8.282	17.855	4.820	6.937	3.863	3.849	3.345	2.165	2.707	0.092
27	9	0	10.9	10.9	8.282	26.137	4.505	11.441	3.512	7.361	2.986	5.152	2.354	2.446
28	10	0	10.9	10.9	8.282	34.418	4.210	15.651	3.193	10.554	2.666	7.818	2.047	4.493
29	11	0	10.9	10.9	8.282	42.700	3.935	19.586	2.903	13.457	2.381	10.199	1.780	6.273
30	12	0	10.9	10.9	8.282	50.982	3.677	23.263	2.639	16.096	2.126	12.325	1.548	7.821
31	13	0	10.9	10.9	8.282	59.264	3.437	26.700	2.399	18.495	1.898	14.223	1.346	9.167
32	14	0	10.9	10.9	8.282	67.545	3.212	29.912	2.181	20.675	1.695	15.917	1.170	10.338

Table 44 – Straight Line Depreciation Economic Calculations

Straightline Depreciation									0.07		0.1		0.12		0.15	
Year	EOY	Outflow	InFlow	CashFlow	Dep	CF-Dep	After Tax CF	Cum AFCF	PW @ 7%	Cum PW @ 7%	PW @ 10%	Cum PW @ 10%	PW @ 12%	Cum PW @ 12%	PW @ 15%	Cum PW @ 15%
19	1	-4.5	0	-4.5	0	-4.5	-3.419	-3.419	-3.195	-3.195	-3.108	-3.108	-3.053	-3.053	-2.973	-2.973
20	2	-21.5	2	-19.5	0	-19.5	-14.816	-18.235	-12.941	-16.136	-12.245	-15.353	-11.811	-14.864	-11.203	-14.176
21	3	-21.5	7	-14.5	0	-14.5	-11.017	-29.252	-8.993	-25.129	-8.277	-23.630	-7.842	-22.706	-7.244	-21.420
22	4	0	18.4	18.4	1.21794872	17.1820513	14.273	-14.979	10.889	-14.241	9.748	-13.882	9.071	-13.635	8.160	-13.259
23	5	0	10.9	10.9	1.21794872	9.68205128	8.574	-6.405	6.113	-8.127	5.324	-8.558	4.865	-8.770	4.263	-8.996
24	6	0	10.9	10.9	1.21794872	9.68205128	8.574	2.169	5.713	-2.414	4.840	-3.718	4.344	-4.426	3.707	-5.290
25	7	0	10.9	10.9	1.21794872	9.68205128	8.574	10.744	5.340	2.926	4.400	0.682	3.879	-0.547	3.223	-2.066
26	8	0	10.9	10.9	1.21794872	9.68205128	8.574	19.318	4.990	7.916	4.000	4.682	3.463	2.916	2.803	0.737
27	9	0	10.9	10.9	1.21794872	9.68205128	8.574	27.892	4.664	12.580	3.636	8.319	3.092	6.008	2.437	3.174
28	10	0	10.9	10.9	1.21794872	9.68205128	8.574	36.466	4.359	16.939	3.306	11.624	2.761	8.769	2.119	5.294
29	11	0	10.9	10.9	1.21794872	9.68205128	8.574	45.041	4.074	21.012	3.005	14.630	2.465	11.233	1.843	7.137
30	12	0	10.9	10.9	1.21794872	9.68205128	8.574	53.615	3.807	24.819	2.732	17.362	2.201	13.434	1.603	8.739
31	13	0	10.9	10.9	1.21794872	9.68205128	8.574	62.189	3.558	28.377	2.484	19.845	1.965	15.399	1.394	10.133
32	14	0	10.9	10.9	1.21794872	9.68205128	8.574	70.763	3.325	31.702	2.258	22.103	1.754	17.154	1.212	11.344

Table 45 – 150% Declining Balance Depreciation Economic Calculations

150% Declining Balance	R	0.0384615							0.07		0.1		0.12		0.15	
Year	EOY	Outflow	InFlow	CashFlow	Dep	CF-Dep	After Tax CF	Cum AFCF	PW @ 7%	Cum PW @ 7%	PW @ 10%	Cum PW @ 10%	PW @ 12%	Cum PW @ 12%	PW @ 15%	Cum PW @ 15%
19	1	-4.5	0	-4.5	0	-4.5	-3.419	-3.419	-3.195	-3.195	-3.108	-3.108	-3.053	-3.053	-2.973	-2.973
20	2	-21.5	2	-19.5	0	-19.5	-14.816	-18.235	-12.941	-16.136	-12.245	-15.353	-11.811	-14.864	-11.203	-14.176
21	3	-21.5	7	-14.5	0	-14.5	-11.017	-29.252	-8.993	-25.129	-8.277	-23.630	-7.842	-22.706	-7.244	-21.420
22	4	0	18.4	18.4	1.82692308	16.5730769	14.419	-14.833	11.000	-14.129	9.848	-13.782	9.164	-13.542	8.244	-13.176
23	5	0	10.9	10.9	1.7566568	9.1433432	8.704	-6.129	6.206	-7.924	5.404	-8.377	4.939	-8.603	4.327	-8.848
24	6	0	10.9	10.9	1.68909308	9.21090692	8.687	2.558	5.789	-2.135	4.904	-3.473	4.401	-4.202	3.756	-5.093
25	7	0	10.9	10.9	1.62412796	9.27587204	8.672	11.230	5.400	3.266	4.450	0.977	3.923	-0.279	3.260	-1.833
26	8	0	10.9	10.9	1.5616615	9.3383385	8.657	19.887	5.038	8.304	4.038	5.015	3.496	3.217	2.830	0.997
27	9	0	10.9	10.9	1.5015976	9.3984024	8.642	28.529	4.701	13.005	3.665	8.680	3.117	6.334	2.457	3.454
28	10	0	10.9	10.9	1.44384385	9.45615615	8.629	37.158	4.386	17.391	3.327	12.007	2.778	9.112	2.133	5.587
29	11	0	10.9	10.9	1.38831139	9.51168861	8.615	45.773	4.093	21.484	3.020	15.026	2.477	11.588	1.852	7.439
30	12	0	10.9	10.9	1.3349148	9.5650852	8.602	54.375	3.820	25.304	2.741	17.767	2.208	13.796	1.608	9.046
31	13	0	10.9	10.9	1.28357192	9.61642808	8.590	62.965	3.565	28.868	2.488	20.256	1.969	15.765	1.396	10.443
32	14	0	10.9	10.9	1.23420377	9.66579623	8.578	71.544	3.327	32.195	2.259	22.515	1.755	17.520	1.212	11.655

9C. Project Contributions

Table 46 – Contributions for Figures

Figure No.	Figure Title	Figure Credit
Figure 1	Regular vs. Irregular Facility Shape	Dukic
Figure 2	Field Layout Options	Dukic
Figure 3	Routes	Dukic
Figure 4	Traditional Layout	Dukic, Cesnik, and Opetuck
Figure 5	Fishbone Layout	Dukic, Cesnik, and Opetuck
Figure 6	Loading Docks	Tutam and White
Figure 7	Truck Flow	Accorsi
Figure 8	Inbound and Outbound Trucks	Accorsi
Figure 9	Apron Space	Accorsi
Figure 10	Gantt Chart	George
Figure 11	Interior Layout Expected Growth	Suktankar
Figure 12	Alternative Interior Layout Expected Growth	Suktankar
Figure 13	Simulation Process	Suktankar and Geiger
Figure 14	Max Queue Time vs. Number of Bay Doors for 20% Growth	Geiger

Figure 15	Max Queue Time vs. Number of Bay Doors for Expected Growth	Suktankar and Geiger
Figure 16	Parking Lot	Wilson
Figure 17	Cumulative Present Worth Money Over Time	Geiger
Figure 18	Run Setup	Suktankar and Geiger
Figure 19	Create	Suktankar and Geiger
Figure 20	Decide	Suktankar and Geiger
Figure 21	Dispose	Suktankar and Geiger
Figure 22	Record	Suktankar and Geiger
Figure 23	Trucks Leave Dispose	Suktankar and Geiger
Figure 24	Create Outbound	Suktankar and Geiger
Figure 25	Decide 2	Suktankar and Geiger
Figure 26	Simulation Disposal	Suktankar and Geiger
Figure 27	Process	Suktankar and Geiger
Figure 28	Record 2	Suktankar and Geiger
Figure 29	Dispose 2	Suktankar and Geiger

Table 47 – Contributions for Tables

Table No.	**Table Title**	**Table Credit**
Table 1	S-Shape Routing Method	Dukic, Cesnik, and Opetuck
Table 2	Composite Routing Method	Dukic, Cesnik, and Opetuck
Table 3	System Definition Matrix	George
Table 4	Schedule Overview	George
Table 5	Daily Outbound Distribution	Suktankar and Geiger
Table 6	Maximum Difference	Geiger
Table 7	Maximum 20% Growth	Geiger
Table 8	Pallet Size Dimensions	Suktankar and Geiger
Table 9	Inventory Sq. Feet	Suktankar and Geiger
Table 10	20% Growth Inventory Sq. Feet	Suktankar and Geiger
Table 11	Inbound Truck Maximum	Suktankar and Geiger
Table 12	Inbound Truck 20% Growth	Suktankar and Geiger
Table 13	No Growth	Suktankar and Geiger
Table 14	20% Growth	Suktankar and Geiger
Table 15	Process Analyzer for 20% Growth	Suktankar and Geiger
Table 16	Process Analyzer at Expected Growth	Suktankar and Geiger
Table 17	Total Sq. Footage	Wilson
Table 18	Background Information	Manufacturing Company

Table 19	No Depreciation	Geiger
Table 20	No Depreciation IRR	Geiger
Table 21	Straight Line Depreciation	Geiger
Table 22	Straight Line Depreciation IRR	Geiger
Table 23	Declining Balance Depreciation	Geiger
Table 24	Declining Balance Depreciation IRR	Geiger
Table 25	Contact Information	George
Table 26	Crate Dimensions	Manufacturing Company
Table 27	Production Data A	Manufacturing Company
Table 28	Production Data B	Manufacturing Company
Table 29	Production Data C	Manufacturing Company
Table 30	Production Data D	Manufacturing Company
Table 31	Production Data E	Manufacturing Company
Table 32	Production Data F	Manufacturing Company
Table 33	Production Data G	Manufacturing Company
Table 34	Production Data H	Manufacturing Company
Table 35	Sales Data A	Manufacturing Company
Table 36	Sales Data B	Manufacturing Company
Table 37	Receipts A	Manufacturing Company
Table 38	Receipts B	Manufacturing Company
Table 39	Ending Inventory A	Manufacturing Company
Table 40	Ending Inventory B	Manufacturing Company
Table 41	Total Production A	Manufacturing Company
Table 42	Total Production B	Manufacturing Company
Table 43	No Depreciation Economic Calculations	Geiger
Table 44	Straight Line Depreciation Economic Calculations	Geiger
Table 45	150% Declining Balance Depreciation Economic Calculations	Geiger

APPENDIX D: REFLECTIONS (THE EDUCATIONAL EXPERIENCE, CHALLENGES FACED, RESOLUTIONS)

Chantal – The educational experience was very beneficial for us. I think it gave us a great real-world experience. One of the challenges faced was having to communicate entirely through email for the most part. For example, when one of us had a question, we would have to be extremely descriptive within the email. Our resolution to the problem was we drew pictures and graphics in order to explain to the manufacturing company engineers what we were trying to describe.

Eric - When conducting research, there were many studies done on facility layouts and designs. However, many of the research done suggested the same approach. Even though there was ample amount of research. There was not a variety of approaches and designs for optimal layouts. Many of the research done had to be broken into specific segments that lead to same objective of optimizing flow of goods through out a facility.

Pete – There were a lot of considerations for both the design of the exterior and interior of the facility. If we had more time, we could have taken into account for office spaces and employee staging areas. All of such would impact the spacing and size of the facility. Overall, we conducted a thorough senior design project.

Matthew - The application of economic analysis was made clear through this project. I understand the economics in theory, but how the company determined cash flows in this project through cost saving gave the theory meaning and provided me a deeper understanding. It was difficult to find the proper depreciation method that should be applied using MACRS depreciation. To overcome this issue, I provided the two most likely methods in straight line and 150% declining balance depreciation methods. When simulating the bay doors utilization, software limitations made modelling the use of the bay doors realistically. This was solved in a number of different ways including using a decide function to determine if the truck was arriving when it should. All of these methods required out of the box thinking and illustrated the importance of creativity.